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HPCBS

High Performance Commercial Building Systems

Evaluation of Persistence of Savings from SMUD Retrocommissioning Program

Final Report

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Executive Summary

Commercial building retrocommissioning activity has increased in recent years. Retrocommissioning is a process of identifying and implementing system improvements in existing buildings, with an emphasis on using low cost operation & maintenance tune-ups and diagnostic testing instead of capital intensive retrofits.

This report discusses a recent study of retrocommissioning persistence, conducted by LBNL for the Sacramento Municipal utility District (SMUD). The objective of this study was to examine a selection of the 17 buildings (prior to 2003) that participated in SMUD's program and estimate the persistence of energy savings and measure implementation. The SMUD retrocommissioning program's two primary goals are to reduce overall building energy consumption and guide the customer toward more far-reaching improvements and energy efficiency awareness.

The complete report contains the following documents:

- Executive Summary & Final Report
- Appendix A: Data Analysis Methodology Details
- Appendix B: Site-by-Site Energy Analysis Results
- Appendix C: Interview Notes - Raw Data
- Appendix D: Data Analysis Spreadsheet

The Report is organized in five sections. The Introduction describes retrocommissioning background, persistence of savings issues and previous related work. The Methodology section provides an overview of the data analysis procedures. The Results and Discussion sections highlight and interpret key findings. The Summary section provides conclusions and recommendations.

Data Collection & Analysis

The project phases progressed as follows:

- A background review of persistence work,
- Development a of project plan and site selection,
- Data collection and analysis, and
- Development of recommendations and the final report.

The selected sites included six office buildings, one hospital and one laboratory. For report distribution and to protect the privacy of the study sites, the locations have been kept anonymous. Anonymity was not implemented in Appendix D because of the difficulty of doing so in the large spreadsheet. For this reason, public distributions of this report will not include Appendix D without SMUD's prior approval.

Retrocommissioning Participants in Year 1999

• Office1	(352,000 ft2)	Construction year unknown
• Hospital1	(267,000 ft2)	Const. in 1996
• Office5	(150,000 ft2)	Const. in 1995
• Lab1	(94,000 ft2)	Const. in 1997

Recommissioning Participants in Year 2000

- Office6 (308,400 ft2) Const. in 1965, complete renovation 1999
- Office2 (383,200 ft2) Const. in 1984
- Office3 (400,000 ft2) Const. in 1991
- Office4 (324,000 ft2) Const. in 1990

Results

The weather normalized energy savings analysis shows an average of 7.3% (4.9% median) annual electricity savings across all eight sites. The retrocommissioning reports predicted an average electricity savings of 4.9% per year (4.0% median) for all eight sites. Post-retrocommissioning savings were on average about 27.5% higher than the report predictions. Natural gas data was not obtained for all eight sites. The four sites with data had and average gas savings of 2.9% (3.3% median). Since the cooling season dominates energy use in Sacramento, the lower natural gas savings only reduced the whole building energy savings to an average of 6.1% (5.4% median).

The aggregate post-retrocommissioning electricity savings calculated by the data analysis are as follows:

Table ES - 1: Aggregate annual energy savings for all 8 sites

Year	2000	2001	2002	2003
Aggregate Savings (MWh/yr)	1,170	4,420	3,850	3,300

The following graph shows the aggregate energy savings with the data in a retrocommissioning year progression instead of calendar year. Each curve represents an aggregate group of sites with the same amount of post-retrocommissioning consumption data. All the sites show increasing energy savings during years one and two. This is expected because the recommended measures are implemented over time (often over a period exceeding one year in duration). After the second year, the increasing savings trend appears to flatten during year three, then degrade in the fourth year.

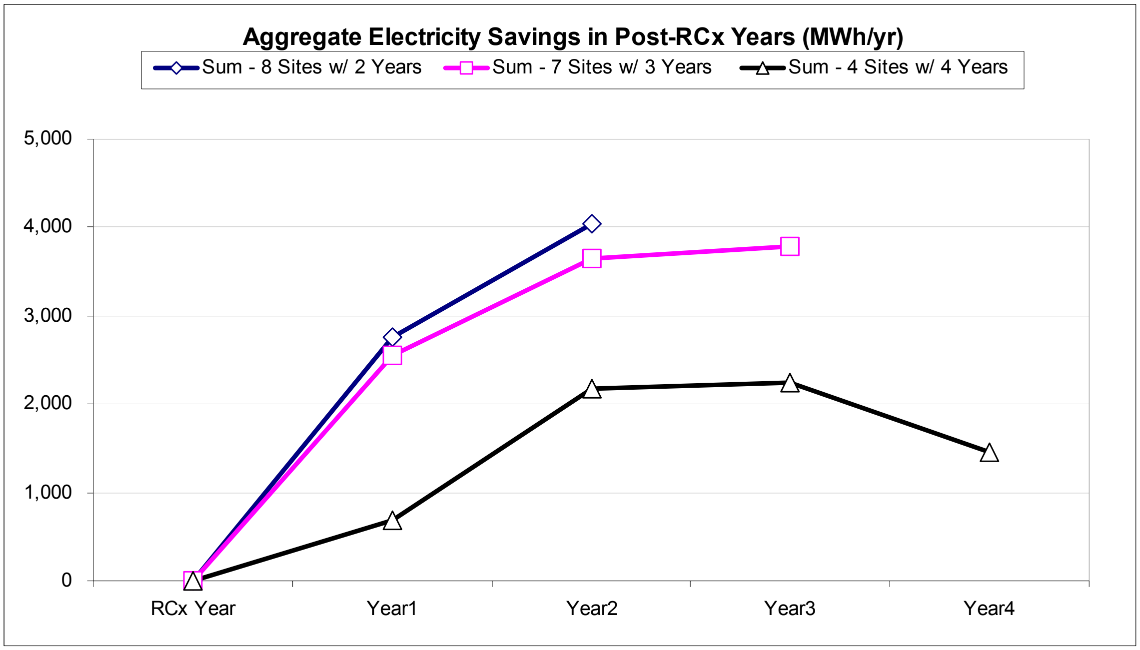

Figure ES - 1: Plot of aggregate post-retrocommissioning electricity savings

The retrocommissioning cost payback was less than three years at each site. The total implementation cost was $61,646 for the 48 recommended measures, an average of approximately $1280 per measure. Floor area normalized retrocommissioning and implementation costs averaged $0.12 per square foot, ranging from $0.06 to $0.41 site by site.

Recommended measures were implemented at a rate of 59% (48 out 81 measures). Implemented measure persistence was strong with an 81% persistence of the recommended system settings. Only four measures were identified as abandoned and not persisting. All four of the not-persisting measures were control recommendations for air distribution components. Five implemented measures did not solve the identified problem, but the sites opted to evolve the settings towards a solution, rather than revert to the pre-retrocommissioning settings.

All of the sites reported that retrocommissioning is a worthy process. Four of the sites listed training as the primary non-energy benefit from retrocommissioning. The most cited downside to retrocommissioning was the time intensive nature of the process.

All of the sites came out of the retrocommissioning process with ideas on how to retain the commissioning benefits over time, the most common solutions being preventative maintenance plans. All the sites would undertake retrocommissioning again, but only two have potential internal funding.

Summary

Some important retrocommissioning process factors that this study identified are:

- The commissioning authority is most effective when they are both an expert and a teacher

- Building engineers prefer to evolve the settings on a recommendation that doesn't work, rather than revert to the previous condition.
- Retrocommissioning appears to raise energy efficiency awareness
- Retrocommissioning funds are constrained within building management budgets

The energy analysis results showed:

- Analyses should not emphasize first-year savings because savings typically take two to three years to fully manifest.
- Energy savings is persisting to four years or more, although some degradation begins in the third year
- The retrocommissioning energy use predictions were reasonably accurate
- Building managers lack tools for tracking energy performance
- Retrocommissioning cost pay back was shorter that the apparent savings persistence
- Retrocommissioning focused mostly on electricity savings and some natural gas trade offs in the savings occurred

Recommended Process Improvements

There are several recommendations that this study can provide to the SMUD Retrocommissioning program:

- Develop measure implementation tracking agreements, possibly with inspections
- Explore methods to conduct a three year post-retrocommissioning energy consumption analysis using the billing history
- Develop simple Performance Tracking Tools for the building operators
- Develop an extension to the program whereby participants are eligible for new incentives in year 4 to evaluate and update the retrocommissioning as necessary

On the whole, the SMUD retrocommissioning program's two broad goals appear to have been met at these eight sites. Aggregate post-retrocommissioning savings were strong, peaking at approximately 4,420 MWh and the program has helped educate site staff about energy efficiency and the role operations and maintenance plays.

I. Introduction

A. Project Goals and Objectives

Commissioning of existing buildings is an increasingly important tool for building owners and operators. Large commercial buildings have many energy consuming systems that will degrade or fail without preventative maintenance and attention. The retrocommissioning process is fast emerging as a cost effective method to fine tune or correct problems, often resulting in energy and cost savings. Although retrocommissioning is becoming popular, the question of how long the benefits will endure over time is not well understood.

The Sacramento Municipal Utility District (SMUD) is a public electric utility serving over 500,000 customers. The SMUD retrocommissioning program is designed to reduce overall building energy consumption through low-cost operational improvements and on-site training of building operators. A secondary goal is to guide the customer toward more far-reaching improvements that may become evident in the course of commissioning. Such improvements may include capital intensive energy efficiency retrofits, more advanced operator interface and software, and replacement of the entire controls system and associated equipment.[i]

Retrocommissioning can be defined as follows.[ii]

> Commissioning of existing buildings or "retrocommissioning," is a systematic process applied to existing buildings for identifying and implementing operational and maintenance improvements and for ensuring their continued performance over time. Retrocommissioning assures system functionality. It is an inclusive and systematic process that intends not only to optimize how equipment and systems operate, but also to optimize how the systems function together. Although retrocommissioning may include recommendations for capital improvements, the primary focus is on using O&M tune-up activities and diagnostic testing to optimize the building systems. Retrocommissioning is not a substitute for major repair work. Repairing major problems is a must before retrocommissioning can be fully completed (Oregon Office of Energy, March, 2001).

Obtaining an estimate for the energy savings persistence is difficult due to the many load and occupancy factors. Equally difficult is characterizing the recommended system settings persistence. Building operators often make modifications to system settings in response to ongoing occupant calls. Over time the changes might adversely affect the previously implemented retrocommissioning measures. More understanding of these two persistence conditions will help retrocommissioning attain even more market penetration.

The objective of this study was to examine the current energy performance of buildings that participated in SMUD's commercial building retrocommissioning program and evaluate the persistence of energy savings and extent of recommended measure implementation. Recommendations are then developed to help improve the effectiveness of the program.

This report is organized in five sections. The remainder of the Introduction describes previous related work and the Methodology section provides an overview of the data analysis. Next, the Results and Discussion sections summarize key findings. The Summary section provides conclusions.

B. Previous Commissioning Persistence Studies

Two previous studies have also examined persistence of savings from commissioning. The first study by Texas A&M was a quantitative examination of the persistence of savings in ten existing buildings. They evaluated whole-building energy use data for several years after commissioning.[iii] Texas A&M refers to existing building commissioning as Continuous Commissioning, but it is quite similar to the retrocommissioning of the SMUD program. The Texas A&M study showed that 3 to 4 years after commissioning, about 80% of the energy savings were still present in the 10 buildings studied. The 20% reduction in savings was dominated by an increase in energy use at 2 of the 10 buildings. So, in general, the persistence of savings was quite good. The study included an examination of the status of each of the measures originally included in the retrocommissioning intervention. Several control measure fixes were defeated.

The second study by PECI,[iv] looked at the persistence of savings in new building commissioning and focused on control system changes. The PECI study used a qualitative approach based on interviews, and site visits were conducted. Individual recommended measures were tracked and evaluated. Fifty-five commissioning fixes were studied, and the large majority of the measures persisted. 14 of the 55 did not persist, or about one fourth.

II. Methodology

This study was conducted with six tasks. The first was a review of existing data for the SMUD retrocommissioning program. Next a review of existing persistence literature and decisions on the project methodology were finalized. The next task was to complete a final project plan and site selection. The next steps were the on-site interviews and the final collection of energy use data. Next the data were evaluated and persistence levels were estimated. Finally, the development of recommendations to improve the retrocommissioning program and improve overall persistence were assembled.

A. Site Selection

SMUD provided LBNL with 12 BAS (Building Automation Systems) retrocommissioning reports as well as SMUD's Evaluation reports for the Year 1999 and 2000 Program participants. The Evaluation reports are SMUD's official record of the measures thought to be implemented.

The selected sites included six office buildings, one hospital and one laboratory. Two of the sites, Office1 and Office3, have computer data centers.

Retrocommissioning Participants in Year 1999

- Office1 (352,000 ft2) Construction year unknown
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- Office3 (400,000 ft2) Const. in 1991
- Office4 (324,000 ft2) Const. in 1990

B. Site Visit Procedures

Sites visits and multiple telephone interviews with each site were conducted. Our methodology to minimize errors involved asking many questions about the same measures over an extended period of the study. This process is discussed more in the measure persistence methodology section.

For each site visit, LBNL prepared a Project Summary & Interview Questions document, which was provided to each site contact person prior to the visit. The document included a summary of the project goals, commissioning practice references, the preliminary energy analysis results, a list of questions about their retrocommissioning experience and formatted tables for answering questions about the recommended measures and their implementation status.

C. Energy Analysis

Both the Energy Analysis and the Measure Persistence work incorporated elements from the two prior relevant studies discussed in the Introduction. The energy analysis process included three phases: analysis of the local weather history, the production of weather normalized energy consumption data and the comparison of consumption history against a pre-retrocommissioning baseline year. During the last step, adjustments to correct for the 2001 energy crisis and other confounding occupancy patterns were attempted.

Spreadsheets and EModel[v], a weather normalization and energy savings analysis tool, were used to estimate the energy use after retrocommissioning. A more detailed discussion of each analysis phase is documented in Appendix A.

1. Billing History Data

Monthly electricity billing history was obtained for all eight sites. One site had two years of post-retrocommissioning data, three had three years, three sites had four years and the last one had five years. At four sites, 15-minute interval data from a web-based energy information system were also available. This data provided the study some end use metering. Monthly natural billing history was obtained for four sites.

Gaps in utility billing data were filled using data from on site records, or EModel regression estimates.

2. Data Normalization

All of the energy consumption data were normalized to a common average weather year and a common billing period of 30.5 days. This was done with EModel and spreadsheet calculations. This is similar to the methodology used by Texas A&M[vi], with the exception that this study uses an average weather year for all the sites as opposed to selecting a representative year from the actual weather data for each site.

Weather data for Sacramento, CA was obtained from the Average Daily Temperature Archive website (http://www.engr.udayton.edu/faculty/jkissock/weather)[vii]. A regression model was applied to each year of 1997 to 2003 data to produce a monthly profile of average dry bulb temperatures.

The EModel simulations produced weather-normalized energy usage profiles based on monthly energy use versus average monthly outside air temperature. More details on the EModel procedure are provided in Appendix A and detailed output for each site is provided in Appendix B. Conducting the weather and billing period normalization was a core aspect of this study. Having the normalized data allowed quick baseline year adjustments without redoing the EModel simulations. Moreover, the program-wide averages and comparisons are more robust with the normalized data.

3. Savings Calculation

Spreadsheets were used to calculate energy savings and energy use benchmarks. Two sets of savings estimates were calculated, using the normalized consumption data the other using the retrocommissioning report predictions. Both sets of savings (columns C & D in Table 2, p.11) were calculated against the same normalized baseline. The savings predictions were done measure-by-measure in the retrocommissioning report. Two of the retrocommissioning reports, Lab 1 and Hospital 1, included a 20% savings discount for the all-measures total. The only calculation explanation provided by the two reports is that the “percentage reduction estimate is considered to give a conservative savings total.” The other six reports did not discuss the issue of interactive effects. The Table 2 results are based on the average annual savings of only the implemented measures, calculated as the mean difference of each post-retrocommissioning year’s electricity consumption against the baseline year.

At Office 2, new chillers were installed in 2002. The savings estimates for Office 2 in this report have been adjusted with chiller plant sub meter data to eliminate the savings associated with the capital intensive retrofit.

The energy cost savings calculation used the average utility rate as documented by the retrocommissioning report. Electric demand charges are not included in the average electricity rate and demand reductions were not tracked by this study.

During the interviews, retrocommissioning and measure implementation costs were gathered. The costs fell into three categories: SMUD’s retrocommissioning costs, the Site’s retrocommissioning costs and the Site’s retrocommissioning measure implementation costs. The cost to SMUD at each site was $25,000. The Site’s retrocommissioning costs were defined as any costs the site absorbed to accommodate the commissioning team's field work (e.g., billed time to generate BAS trends, building engineer escorts, etc.). The measure implementation costs include the material and time costs. This category has the widest margin of error, because all of the sites were innovative at finding ways to implement the measures they wanted. In many instances they found “in-between” time for their staff to do the work or found ways to include the work within the scope of service contracts already in place. At two sites, Office1 and Office6, the building engineers provided one implementation cost estimate for all the implemented measures.

A cost effectiveness estimate of the retrocommissioning program was conducted by calculating simple paybacks using the sum of the three cost categories. Paybacks were calculated for the savings predicted by the retrocommissioning report and from the normalized consumption data. The results are presented in Table 7(p.16).

More detailed documentation of analysis calculations are provided in the Appendix A discussion and the Appendix D spreadsheet (CD provided with Hard copies).

D. Measure Persistence Analysis

The measure persistence analysis used site visits and interviews to determine the current status of the recommended measures. A three-phase interview method was used to improve accuracy. The first phase consisted of a questionnaire provided prior to the initial site visit. At the site visit, if access to the BAS was available the measure settings were checked. The second phase involved telephone interviews in which all the measure implementation questions were rephrased and posed again. The third phase was yet another round of telephone interviews, as well as email correspondence, but this time the questions were limited to the discrepancies uncovered between the first two phases.

Parts of the interview history are documented in the spreadsheet (Appendix D) used to finalize the energy analysis. Additional questions about the retrocommissioning process and its effect on building operations, Table 10 (p.19), are documented in the Appendix C interview.

In an effort to track measure persistence trends, each recommended measure was assigned a component letter code and an intervention strategy code. The categories are listed in Table 1. For example, a recommendation to modify the supply air reset schedule of an air handler would be assign the code A-CR1.

Table 1: Measure category key

Measure Categories			Code Letters
Component	Cooling plant		C
	Heating plant		H
	Air distribution		A
	Lighting		L
	Plug Loads		R
	Whole Buidling		W
Strategies	Design, Installation	Change equipment	DI1
		Install controller	DI2
	Control	Reset	CR1
		Sart/Stop	CR2
		Scheduling	CR3
		Modify setpoint	CR4
		Calibration	CR5
	O&M	Manual operation	OM1
		Maintenance	OM2

After the current measure status was determined, we identified each implemented measure as being in one of three persistence states: 1) persisting as implemented, 2) not-persisting as implemented or 3) evolved from the originally implemented settings. The third category for measures that are ‘evolved’ was added to capture measures that were tried, but eventually changed to something fundamentally different than the original settings. The results of the implemented measure survey are presented in Table 8 (p.17).

III.Results

A. Energy Savings

The energy savings analysis shows an average of 7.3% (4.8% median) electricity savings per year across all eight sites. The retrocommissioning reports predicted an average electricity savings of 5.6% per year (4.0% median) for all eight sites. The predicted savings totals are limited to the recommended measures that were implemented.

Table 2: Summary of electric savings

Building	A Predicted Avg Annual Elec.savings (MWh/yr)	B Post-RCx Avg Annual Elec.savings (MWh/yr)	C Predicted Avg Annual Elec.savings (%)	D Post-RCx Avg Annual Elec.savings (%)	E Baseline Electricity (MWh/yr)	B/A Percent of Post-RCx vs Predicted Elec. Savings
Office1	380	190	7.3%	3.6%	5,210	50%
Office2	490	360	7.5%	5.5%	6,604	73%
Lab1	520	620	16.1%	19.3%	3,190	119%
Hospital1	460	430	4.7%	4.4%	9,850	93%
Office3	90	300	1.0%	3.4%	8,584	333%
Office4	120	290	2.2%	5.4%	5,327	242%
Office5	170	220	3.4%	4.3%	4,996	129%
Office6	140	610	2.9%	12.5%	4,827	436%
All Sites	2,360	3,010	4.9%	6.2%	48,588	128%

Column B/A of Table 2 compares the difference between predictions and the calculated electricity savings. Post-retrocommissioning savings were on average about 27.5% higher than the report predictions. Three sites had predictions that were larger that the post-retrocommissioning energy use. The retrocommissioning reports predicted an average annual savings of 2,360 MWh per year and the actual energy use reductions are estimated at approximately 3,010 MWh.

Table 3: Summary of electricity savings by year

Baselines are shaded		1998	1999	2000	2001	2002	2003
Office1 *	% Savings		**0%**		5%	2%	0%
	EUI **		**33.7**		32.7	33.2	34.6
	MWh/yr		**0**		270	130	10
Office2	% Savings			**0%**	15%	11%	15%
	EUI			**17.2**	14.7	15.4	14.7
	MWh/yr			**0**	970	700	990
Lab1	% Savings	**0%**	2%	16%	29%	26%	24%
	EUI	**33.9**	33.4	28.4	24.2	25.0	26.0
	MWh/yr	**0**	50	530	910	840	750
Hospital1	% Savings		**0%**	4%	6%	8%	5%
	EUI		**37.4**	35.9	35.2	34.5	35.6
	MWh/yr		**0**	390	590	770	470
Office3	% Savings		**0%**	4%	5%	3%	-2%
	EUI		**21.7**	21.0	20.6	21.1	22.2
	MWh/yr		**0**	310	440	230	-180
Office4	% Savings				**0%**	4%	7%
	EUI				**16.4**	15.8	15.3
	MWh/yr				**0**	200	380
Office5	% Savings		**0%**	-1%	12%	6%	6%
	EUI		**14.7**	14.8	12.9	13.7	13.7
	MWh/yr		**0**	-60	620	330	330
Office6	% Savings			**0%**	13%	13%	11%
	EUI			**15.7**	13.6	13.5	13.9
	MWh/yr			**0**	620	650	550
All Sites - Total MWh			**0**	**1,170**	**4,420**	**3,850**	**3,300**

* Estimated Baseline from 1998 - 2000 data. ** Energy Use Intensity (kWh/sf^2 yr)

Table 3 shows the calculated post-retrocommissioning energy savings and Energy Use Intensities (EUI) for each year. The annual totals show that these eight sites produced a peak electricity savings of 4,420 MWh in 2001.

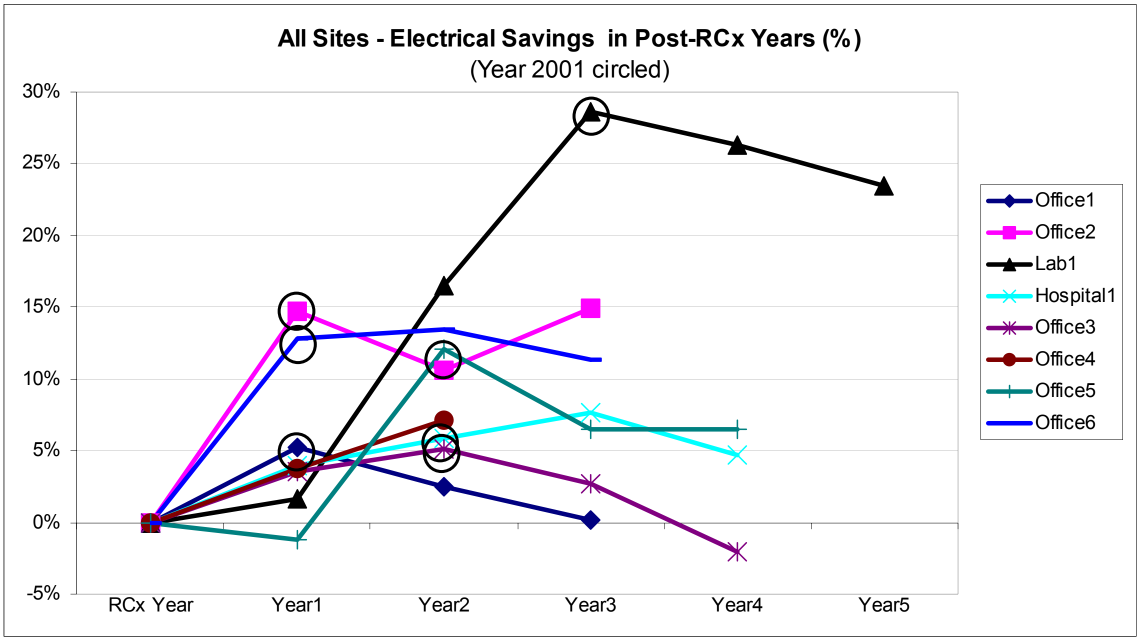

Figure 1: Electrical energy savings in post-rcx years (%)

Figure 1 shows the percent energy saved at each site versus a retrocommissioning year progression. Seven of the sites had 2001 fall into post-retrocommissioning years, as indicated with circles on Figure 1. The curves show that at four sites, 2001 was the peak post-retrocommissioning electricity savings year. This may be a significant trend that shows those sites increased energy conservation activity due to the 2001 California energy crisis.

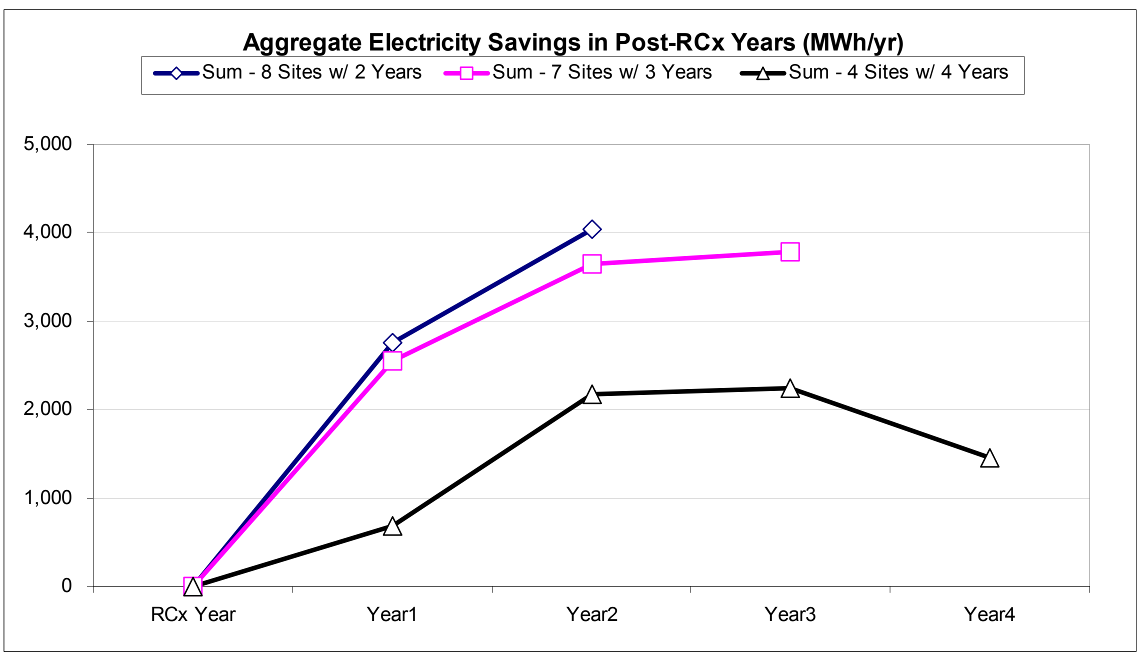

Figure 2: Plot of aggregate post-retrocommissioning electricity savings

Figure 2 shows the energy saved when the data are arranged by years after the retrocommissioning baseline. Each curve represents an aggregate group of sites with the same amount of post-retrocommissioning consumption data. All the sites show increasing energy savings during years one and two. This is expected because the recommended measures are implemented over time. After the second year, the increasing savings trend appears to flatten during year three, then begin to reduce in the fourth year.

Table 4: Electricity savings in post-commissioning years (MWh/yr)

(2001 years are shaded)	RCx Year	Year1	Year2	Year3	Year4	Year5
Office1	0	270	130	10		
Office2	0	970	700	990		
Lab1	0	50.0	530	910	840	750
Hospital1	0	390	590	770	470	
Office3	0	310	440	230	-180	
Office4	0	200	380			
Office5	0	-60	620	330	330	
Office6	0	620	650	550		
Sum - 8 Sites w/ 2 Years	0	2750	4040			
Sum - 7 Sites w/ 3 Years	0	2550	3660	3790		
Sum - 4 Sites w/ 4 Years	0	690	2180	2240	1460	

The values for Figure 2 are listed in Table 4. The Year 2 aggregate has three sites with 2001 data. Approximately 1,860 MWh of the year 1 and 1,650 MWh of the year 2 reductions are from savings occurring in 2001.

Unfortunately, this study did not obtain natural gas consumption for all eight sites. However, the four sites listed in Table 5 provided enough natural gas data, to calculate some whole-building energy results.

Table 5: Four sites – Summary of whole building savings (electricity & n. gas)

Building	A Post-RCx Avg Annual Elec.savings (%)	B Avg Annual N. Gas savings (Therms)	C Post-RCx Avg Annual N. Gas savings (%)	D Baseline Natual Gas (Therms)	E Whole Building Energy (MBtu/yr	F Whole Building EUI (kBtu/ft2 yr)	G Avg Annual Whole Building EUI savings	H Post-RCx Avg Annual Whole Building EUI savings (%)
Office2	5.5%	8,950	15.7%	57,100	28,300	74	5.6	7.6%
Hospital1	4.4%	4,990	1.8%	277,100	60,800	228	7.4	3.2%
Office4	5.4%	-3,370	-10.7%	31,500	3,000	65	2.0	3.1%
Office6	12.5%	2,690	4.8%	55,700	21,900	71	7.6	10.7%
All Sites	7.3%	13,260	2.9%	421,400	114,000			6.1%

A problem with the natural gas analysis was that the retrocommissioning reports rarely provided a prediction for the natural gas consumption. At the four sites with natural gas data, the average electrical savings was 7.3% (7.0% median) but the natural gas consumption was 2.9% (3.3% median). Since the cooling season dominates energy use in Sacramento, the lower natural gas savings only reduced the whole building energy savings to an average of 6.1% (5.4% median) at the four sites (Column H, Table 5).

Table 6: Four sites - Summary of whole building energy (electricity & nat. gas) savings by year

Baselines are shaded		1999	2000	2001	2002	2003
Office2	% Savings		**0%**	16.6%	16.3%	21.2%
	EUI		**73.7**	61.5	61.7	58.1
	MBtu/yr		**0**	4,683	4,598	5,998
Hospital1	% Savings	**0%**	3.4%	7.4%	1.5%	No gas Data
	EUI	**227.6**	220.0	210.8	224.2	
	MBtu/yr	**0**	2,044	4,492	-4,470	
Office4	% Savings			**0%**	3.0%	No gas Data
	EUI			**65.3**	63.4	
	MBtu/yr			**0**	-337	
Office6	% Savings		**0%**	15.5%	7.7%	8.8%
	EUI		**70.9**	59.9	65.4	64.7
	MBtu/yr		**0**	3,387	1,691	1,930
Four Sites - Total MBtu/yr		**0**	**2,044**	**12,563**	**1,482.5**	**7,928**

* EUI values are kBtu/sf^2 yr

Table 6 and Figure 3 show the calculated post-retrocommissioning whole building energy savings and EUI for each year.

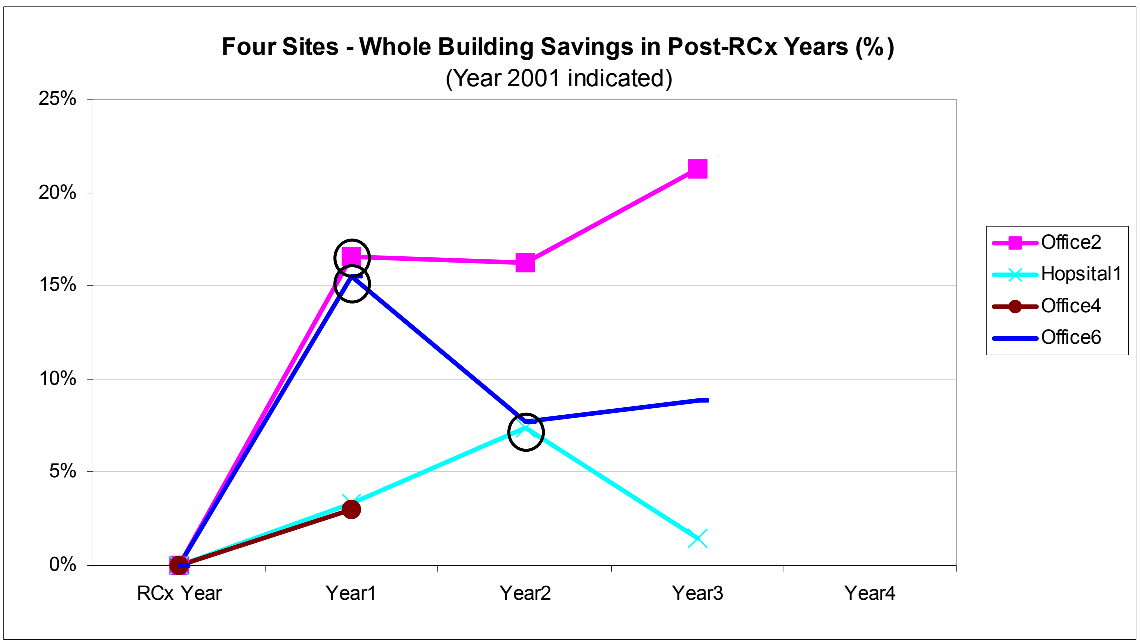

Figure 3: Four sites - Whole building energy savings in post-rcx years (%)

Overall, the inclusion of natural gas data reduced whole building energy savings slightly, but did not significantly change the savings profile.

1. Cost Effectiveness Analysis

Table 7 (p.16) summarizes the retrocommissioning costs and paybacks for each site. All of the implementation costs were moderate, with a total implementation cost of $61,646 for the 48 recommended measures. This total cost excludes a capital-intensive recommendation, at Office 2, to install new chillers, because the chiller change-out is a capital equipment energy savings measure rather than a commissioning measure. Office 3 kept costs down by doing the work under an existing service contract. All the paybacks are attractive. The floor-area-normalized costs ranged from $0.06 to $0.41 per square foot. Compared to traditional capital intensive energy audits, these costs range from opportunity assessment to investment-grade audit prices.

Table 7: Table of retrocommissioning costs & simple paybacks

Building	RCx Study costs (Agent cost $25k, balance incured by site)	Estimated Measure Implmnt. costs	Predicted Avg Annual savings ($)	Post-RCx Avg Annual savings ($)	Predicted Simple Payback	Post-RCx Simple Payback	RCx Study Costs ($/sf)	RCx Study & Implement. Costs ($/sf)
Office1	$28,000	$1,710	$24,500	$13,000	1.2	2.3	$0.19	$0.20
Office2	$26,500	$20,500	$21,900	$27,900	2.1	1.7	$0.07	$0.12
Lab1	$26,000	$12,370	$64,800	$40,100	0.6	1.0	$0.28	$0.41
Hospital1	$28,300	$11,180	$35,200	$30,900	1.1	1.3	$0.11	$0.15
Office3	$25,400	$150	$6,400	$22,400	4.0	1.1	$0.06	$0.06
Office4	$26,817	$8,380	$8,400	$22,600	4.3	1.6	$0.08	$0.11
Office5	$26,817	$4,350	$9,100	$15,800	3.4	2.0	$0.08	$0.09
Office6	$26,700	$3,000	$11,200	$48,600	2.7	0.6	$0.09	$0.10
All Sites	$214,533	$61,650	$181,600	$221,200	1.5	1.2	$0.09	$0.12

B. Measure Persistence

Measure persistence among the implemented recommendations appears to be good, with 81% identified as still persisting with the system settings that were recommended. The current persistence state of the implemented measures are listed in Table 8 (p.17). Only four measures were identified as being abandoned completely and as such are not persisting. All four of the non-persisting measures were control recommendations for air distribution components.

Table 8: Summary of persistence status for implemented measures

	Office1	Office2	Lab1	Hopsital1	Office3	Office4	Office5	Office6
Measure Category Codes	C-CR2(y)	A-CR4(y)	W-OM1(y)	A-CR3(e)	A-CR5(y)	A-CR5(y)	A-DI1(y)	A-CR2(y)
	C-CR2(y)	L-DI2(y)	A-DI2(y)	A-CR4(y)	A-CR1(n)	H-CR2(y)	A-OM2(y)	H-CR2(y)
	H-CR2(y)	C-DI1(y)	A-DI2(y)	A-CR3(y)	C-CR2(n)	A-CR5(n)	A-CR1(n)	C-CR2(e)
	A-CR4(y)		A-CR4(y)	A-CR3(y)		H-CR3(y)	A-OM2(y)	C-DI1(y)
	A-CR5(y)			C-CR4(y)		C-DI2(y)	A-OM2(e)	C-CR4(y)
	L-CR3(y)			C-CR4(y)			A-DI2(y)	C-CR1(e)
				C-DI1(y)			H-CR2(y)	A-CR5(y)
				L-OM1(y)				C-CR1(e)
				L-OM1(y)				
				L-CR3(y)				
				L-DI2(y)				
				L-DI2(y)				
Category & Status ID (y = Persists, n = Not-Persisting, e = Evolved)								

Five implemented measures did not solve the identified problems to the building engineers satisfaction and they chose to evolve the measures to find a better solution. Three are control settings on a cooling plant, and the other two are air distribution measures.

Table 9: Count of implemented & not implemented measure categories

Measure Categories			Code Letters	Implemented Tally	Not Implemented Tally	% Implemented
Component	Cooling plant		C	13	8	62%
	Heating plant		H	5	4	56%
	Air distribution		A	22	13	63%
	Lighting		L	7	5	58%
	Plug Loads		R	0	1	0%
	Whole Buidling		W	1	0	100%
Strategies	Design, Installation	Change equipment	DI1	4	6	40%
		Install controller	DI2	7	4	64%
	Control	Reset	CR1	4	6	40%
		Sart/Stop	CR2	9	1	90%
		Scheduling	CR3	6	2	75%
		Modify setpoint	CR4	7	3	70%
		Calibration	CR5	5	5	50%
	O&M	Manual operation	OM1	3	2	60%
		Maintenance	OM2	3	3	50%

The eight retrocommissioning reports recommended a total of 81 corrective measures and 48 were implemented. Air distribution related measures are the most popular in the list with 43% of the component count. Cooling plant related measures are next with 26% of the count. The distribution of recommended strategies is even, with start/stop controls having a slight edge. Only one of the ten recommended start/stop measure was not implemented. Start/stop measures were defined as equipment control settings that are based on environmental parameters such as outside dry bulb temperature. Scheduling measures were defined as equipment control settings that are occupancy based.

IV. Discussion

In general, based on the energy reduction trends at each site, we found that all of the sites had very good cost effectiveness from the retrocommissioning service. The persistence results in Figure 2 and the payback periods in Table 7 (p.16), show that the cost paybacks are within the time frame of persisting energy savings. The longest payback was two years and Figure 2 shows that on average the savings don't begin to show reduction until the fourth year.

An important factor in this study is that there are confounding effects due to the 2001 energy crisis. Four sites report that they responded to the crisis with operation changes such as de-lamping, turning off unnecessary hallway lighting and softening thermostat settings. The post-retrocommissioning data shows five sites have increased energy savings during 2001. On the same token, passing of the crisis (and reduced attention to energy management) may have contributed in part to the apparent reduction in persistence of the savings.

The energy savings benefits are clearly persisting for three years or more at six sites. Only two sites show sharply reduced energy savings in 2003.

At Office1, the recommended measures are implemented at a high rate and the persistence of recommended settings are also reported as high. This conflicts with the apparent lack of energy savings persistence. This could be due to missing energy consumption data for all of 1999 and most of 2000. Also a factor are difficulties in isolating the energy use of the facility's computer data center, which doubled in size to approximately 9000 ft^2 during 2000. Another factor was difficulty in obtaining information from the site personnel. They were consistent in their survey answers in all three phases, but the systems are actually maintained by a subcontractor that we did not interview.

The Office 3 site reported poor interactions with the retrocommissioning authority during field work. The chief engineer identifies the non-existent training benefit as a major disappointment. He also reports significant errors in the retrocommissioning report. As a result, only one recommended measure was implemented (Table 8, p.17). The measure recommended that all sensors be calibrated, which resulted in immediate energy savings. Their operation now recalibrates all sensors every six months. This facility also has a large computer data center, operated by a tenant. There was no discussion of the computer data center in the retrocommissioning report.

Recommended measures were implemented at a rate of 59% (48 out 81 measures). In 19 cases the recommendations were rejected due to a conflicting opinion about the retrocommissioning analysis or the cost was prohibitive. In seven cases, the sites said they would revisit the measures in the future. Another seven recommended measures have plans for implementation. In at least two cases, erroneous assumptions were made and the recommendations should not have been offered. In both cases, better communication with the building operators would have preempted the recommendations. In three cases, no reasons were provided for rejecting the recommendations.

One measure, wet bulb reset control for the condenser water temperature, was recommended in exactly the same fashion at three sites. All three sites rejected the recommendation. The apparent rejection of the "cookie cutter" measure by all the sites reinforces the importance to keep the retrocommissioning recommendations specific to the facility's systems.

From the outset of data collection, direct access to the candidate buildings for inspections was hampered due to the busy schedules that the building managers, engineers and operators have.

Seven sites reported that the retrocommissioning process inspired a more innovative analysis of their systems and in many cases prompted them to find other retrocommissioning like improvements. This factor is an important benefit that should not be overlooked and is directly related to a retrocommissioning process that involves the building operations staff as much as possible. In a large percentage of instances, a properly executed retrocommissioning process will inspired a more creative approach to building operations and maintenance that might not have previously existed.

Table 10 lists the sites' answers to eight key questions about their retrocommissioning experience. The blank cells mean the site did not answer the question. The complete list of questions and answers for each site are provided in Appendix C.

Table 10: Answers to survey questions about Retrocommissioning process

Building	Primary non-energy impact of RCx	Most negative impact of RCx	Level of Training obtained	Plans to improve persistence	Will you RCx again	Do you have funds for RCx	How did you pay for RCx costs	How did you find out about SMUD RCx
Office1	Review of Sys. Specs.	None		Maintenance Manager program	Yes	No	O&M Budget	SMUD RCx dept.
Office2	Equip. life improvement	Time Req.	High	Utility Manage. plan	Yes	No	O&M Budget	SMUD Rep.
Lab1	Training	Time Req.	High	Improve WO process	Yes	Possible	O&M Budget	SMUD RCx dept.
Hospital1	Training	Time Req.	High	Create an Energy Group	Yes	No	O&M Budget	SMUD Rep.
Office3	Training	None	None	Chief Eng. - approves all changes	Yes	No	O&M Budget	SMUD Rep.
Office4			Low	PM plan	Yes	No	O&M Budget	SMUD Rep.
Office5	Review of Sys. Specs.	Tenant interactions		PM plan	Yes	No	O&M Budget	SMUD Rep.
Office6	Training	Time Req.	High	BAS maint. Contract	Yes	Yes	O&M Budget	SMUD Rep.

Four sites listed training as the most important non-energy benefit. Many of the building engineers characterized the commissioning authority as a "teacher." Table 3 (p.12) results show that the four sites that said that they received a high level of training value also had good energy savings persistence. Conversely, Office3 reported virtually no training value and this site shows poor energy savings persistence.

The most cited downside to retrocommissioning was the time-intensive nature of the process. Also notable are two building engineers that could not find any negative aspects of retrocommissioning. Only one site identified inconvenience to the tenants as a problem.

All of the sites came out of the retrocommissioning process with ideas on how to retain the commissioning benefits over time. The most common solutions are preventative maintenance plans (not all the sites called it a PM plan). Office6 hired a BAS expert with the task of providing small commissioning style reviews each month. The Hospital 1 site is creating an Energy Issues Group among their building operations staff.

All the sites would undertake retrocommissioning again, but only two have the chance for internal funding to do so. The other sites report that they are dependent on external funding for the cost of retaining a commissioning authority.

None of the sites sought out SMUD for the retrocommissioning program. Either their SMUD account representative or an employee of the SMUD commercial building services department recruited them.

An additional comment provided by Office 5 was that the retrocommissioning exposed some errors and inadequacies of the new construction commissioning that was conducted in 1995. For example, they found sensors inside walls and, fundamental duct static pressure and fan speed problems.

V. Summary

The persistence of retrocommissioning benefits, both non-energy and energy related, are significantly affected by how the process is executed. Especially important is the conduct of the commissioning team during field work. Some important process factors that this study identified are:

- **Commissioning authority attitude** – A superior attitude can hinder information flow in the process. Commissioning authorities are most effective when they are both an expert and a teacher.
- **Identification of a retrocommissioning measure is just the start** – Retrocommissioning measures do not always work. Finding options that allow building engineers the opportunity to evolve towards a final solution is desirable.
- **Retrocommissioning can raise energy efficiency awareness** – Independent of whether the retrocommissioning effort was successful, all eight sites exhibited an increased awareness of energy efficiency and building diagnostics issues.
- **Retrocommissioning funds are constrained** – SMUDs program does not provide funds for retrocommissioning project implementation. However, all of the survey sites internally funded projects meeting their cost-effectiveness constraints.

The energy analysis results showed:

- **Measure implementation occurs slowly** – Analyses should not emphasize first-year savings because savings typically take two or more years to fully manifest.

- **Energy savings degraded in the fourth post-retrocommissioning year** – The energy data appears to show that persistence turns a corner after three years and begins to show signs of reduction. However, this finding is confounded by extraordinary energy savings efforts made during the 2001 energy crisis.
- **The retrocommissioning energy use predictions are reasonably accurate** – The retrocommissioning authorities under predicted energy savings at the eight sites by 27.5%.
- **Building managers lack tools for tracking energy performance** - Only 3 of the building operations staff had access to energy consumption analysis tools. The remaining facilities did not have any resources other than monthly utility bills.
- **The cost payback was shorter than the apparent savings persistence** – The calculated simple paybacks were shorter than the four years of energy savings. The results indicate that the complete costs of retrocommissioning could haven been absorbed into the property management's internal budgets.
- **The retrocommissioning focused heavily on electricity savings** – This is a natural expectation since SMUD is not a natural gas supplier and cooling dominates costs in Sacramento. However, the natural gas data show trade-offs between electricity and natural gas consumption at some sites. From the customer's perspective, cost savings might have been improved if the process more carefully considered interactive effects between cooling and heating.

A. Recommended Process Improvements

There are several recommendations that this study can provide to the SMUD Retrocommissioning program:

- **Develop measure implementation tracking agreements** – SMUD's records on the measure implementation status were inaccurate for all eight sites. Project contracts with specific language that provides inspection level access to the system could improve the accuracy.
- **Explore methods that can provide a three year post-retrocommissioning energy consumption analysis** – An EModel style analysis of the program participant's billing history, approximately three to four years after retrocommissioning, could provide better feedback on the savings persistence. This level of analysis can be designed into a relatively low cost production process requiring modest technical skills.
- **Develop Performance Tracking Tools** – All the building engineers expressed a need for performance tracking tools. If adequate tools were available, they could monitor key metrics that indicate when persistence is degrading and quickly respond with corrections.
- **4th Year Retrocommissioning Measures Review** – Consider adding a component to the Program to foster re-assessment of the retrocommissioning measures in the fourth post-retrocommissioning year.

On the whole, the SMUD retrocommissioning program's two broad goals appear to have been met at these eight sites. The goal to reduce overall building energy consumption appears to be fulfilled, with the aggregate post-retrocommissioning savings peaking at approximately 4,420 MWh in 2001. A significant a portion of the savings came from low-cost operational improvements and on-site training of building operators, but an unquantifiable percentage also came from emergency measures associated with the 2001 energy crisis.

SMUD's second goal of guiding their customers toward more far-reaching improvements, is also apparent among these sites. The retrocommissioning process has been a factor in customers' increased awareness of energy efficiency and the positive impact that operations and maintenance can have on energy use.

B. FUTURE DIRECTIONS

Additional research is needed to examine whether the trends identified concerning the persistence of savings from retrocommissioning that occurred in this project are similar at other sites. The findings from this project are similar to the findings from previous research suggesting that most of the savings persist beyond three years. To better estimate of the impact of the 2001 Energy Crisis, these results should be compared against consumption data for similar buildings that did not participate in SMUD's retrocommissioning program. Longer multi-year studies are also needed to examine five year savings rates and beyond. Additional research is also needed to develop tools and methods to allow building engineers and operators to obtain feedback on savings associated with retrocommissioning. Diagnostics tools and continuous performance monitoring systems are needed to assist in such tracking.

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EVALUATION OF PERSISTENCE OF SAVINGS FROM SMUD RETROCOMMISSIONING PROGRAM FINAL REPORT

DATA ANALYSIS METHODOLOGY DETAILS

APPENDIX A

I. Whole Building Energy Analysis

Both the Whole Building Energy Analysis and the Measure Persistence Analysis data analyses incorporated elements from the two relevant studies discussed in the Introduction section.

The energy analysis process included three phases: analysis of the local weather history, the production of weather normalized energy consumption data and the comparison of consumption history against the pre-retrocommissioning baseline year. During the last step, adjustments to correct for the 2001 energy crisis and other confounding occupancy patterns were incorporated.

Spreadsheets and the EModel building energy analysis tool were used to produce estimates of the post retrocommissioning energy savings.

A. Billing History Data

Monthly utility bills for each site were provided by SMUD. At four sites, 15-minute interval data from installed EnerLink systems were also provided. Electricity and some gas data was provided by SMUD. Additional gas data was provided by the site contacts. The Figure 1 graphic summarizes the periods obtained for each site.

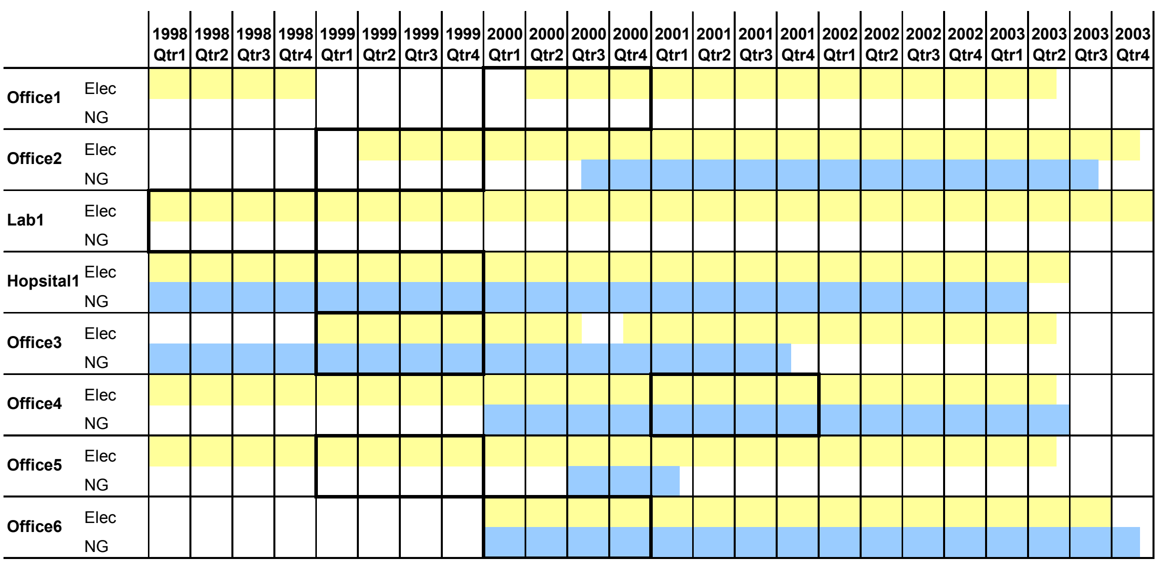


Figure 1: Utility Histories collected

Any remaining holes in the billing histories were filled or estimated using one of the following methods (listed in priority order):

1. From the site contact's records during the initial site visit, or
2. From 15-Minute interval data, or
3. The EModel regression based estimates.

B. Weather Normalization & EModel Details

All eight of the billing histories were normalized to a common average weather year. This was done with EModel and a spreadsheet calculated average weather year for the Sacramento region. This is fundamentally the same methodology used by Texas A&M with the exception that this study uses a calculated average weather year for all the sites. Texas A&M's study selected one year from the actual weather data and adopted it as the "normal" for the region.

The input parameters for EModel are the monthly building electricity or natural gas usage and monthly outside dry bulb temperature. Typically, the billing period varies between 27 days and 34 days. Therefore, the monthly usage was normalized by billing period days (Month-usage divided by the #-of-days in period and multiplied by the average of 30.5 days per month).

Weather data for Sacramento, CA was obtained from the University of Dayton website (http://www.engr.udayton.edu/faculty/jkissock/weather). A regression model (Equation 1) was applied to each year of the 1997 to 2003 range of data.

Equation 1: Average Weather Year Regression Model

$$Y - Ycp = RS * (X - Xcp)$$

Y: Whole building power (WBP), X: Outside air temperature (OAT)

Ycp: Change point of WBP, Xcp: Change point of OAT

RS: Regression slope

Figure 2 shows the monthly average Outside Air Temperature (OAT) trend of each year and the average trend used as the base.

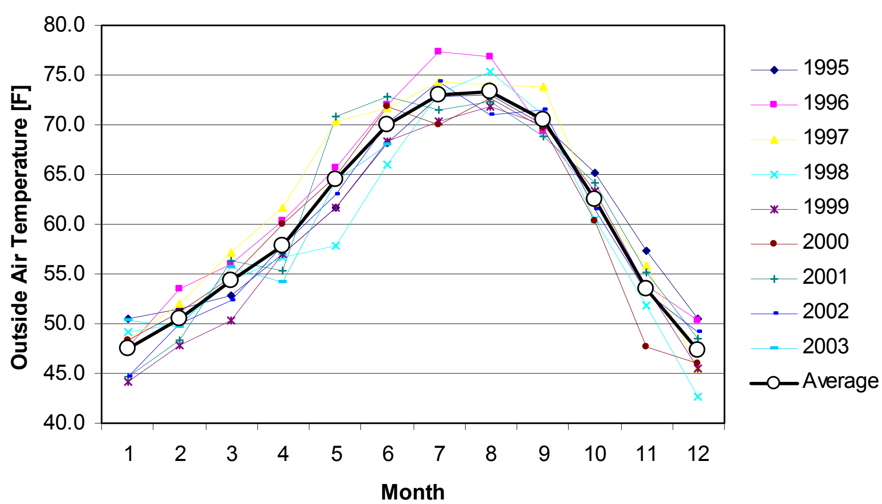


Figure 2: Monthly Average Outside Air Temperature

Using these inputs, the EModel simulation was used to produce a weather-normalized energy usage profile and energy use vs. OAT scatter plots (plots are included in the site results in Appendix B).

Since this study used this normalization methodology, comparisons against any year (e.g., the baseline) in the analysis period were possible without re-running EModel. Additionally, program wide comparisons such as, aggregate savings analysis, retrocommissioning year progression analysis and all sites average annual savings were made possible.

1. EModel - kWh vs. OAT Output

In addition to the weather-normalized energy usage, we used EModel to produce kWh vs. outside air temperature (OAT) scatter plots (site results are in Appendix B). Figure 3 provides a schematic overview of the kWh vs. OAT plots. The EModel regression has a changing point where the cooling mode starts above the OAT. During the heating season, the cooling system is normally not used and whole building electricity usage is dominated by the base load (lights, plugs and elevators). None of the eight sites use electricity as the primary heating source. Though fan power usage can increase in cold seasons due to increase of heating, it is not counted in this analysis.

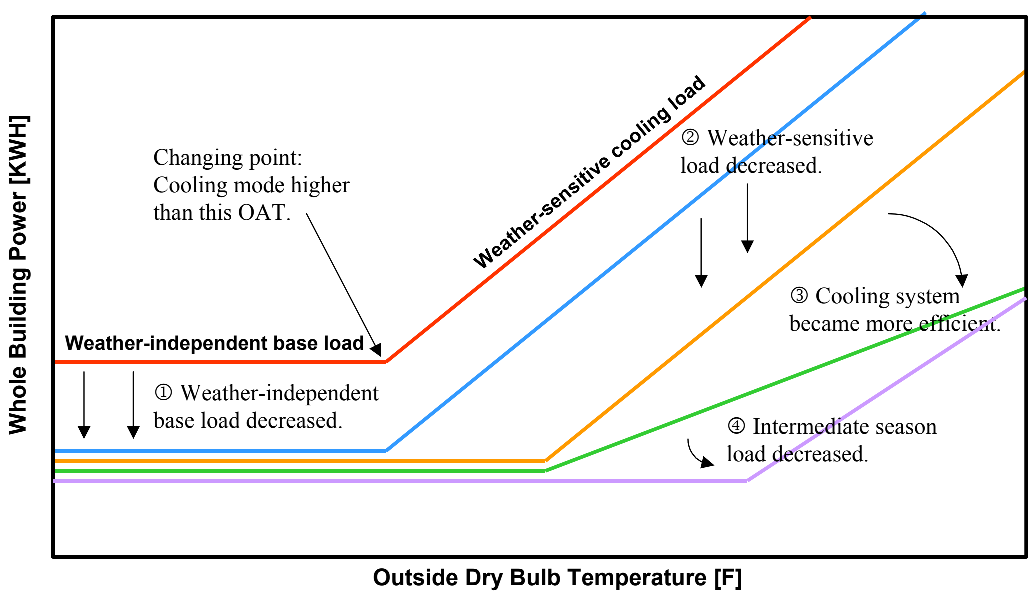


Figure 3: EModel Interpretation

There are four significant trends to note in the kWh vs. OAT plots graphs:

(1) Changes in weather independent loads

When the horizontal line below the changing-point shifts down, it indicates a weather-independent base load decrease compared to previous years.

(2) Changes in weather dependent loads

When the sloped line above the changing-point shifts down, without lowering the base load (trend 1) or a change in slope, this indicates a decrease in weather-dependent load.

(3) Changes in cooling system efficiency

When the slope of the weather-dependent load line shifts towards horizontal, it indicates the cooling system became more efficient. This effect is not as identifiable when the cooling load is low (near changing-point), but becomes larger as OAT increases.

(4) Changes in the intermediate season length

When changing-point moves to higher OAT, while power usage stays at the same level in the maximum OAT range, it indicates intermediate season (spring and fall) loads have decreased. Although energy usage in peak summer period doesn't decrease, low capacity inefficient operation or unnecessary operation can be improved.

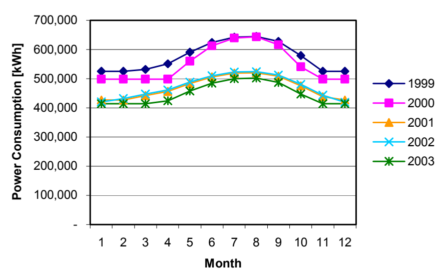
Interpretation of the kWh vs. OAT plots can be tricky, because combinations of key trends can appear like another. For example, combination of 3 and 4 may appear like a trend of 2. As a result, final analysis should also take measure analysis and spreadsheet calculations into consideration.

2. EModel – Consumption Data Output

An example of the normalized consumption data provided by EModel is shown in Figure 4. The top table and graph represent the typical normalized output that was produced for each site (results are provided in Appendix B). The bottom table and graph represents an input from the billing period normalized actual data. Notice that this example shows that the regression model is able to accommodate large holes in the billing data.

E-Model

		1999	2000	2001	2002	2003
Ycp		525520	498260	427335	410399	414272
Xcp		53.4	57.9	50.9	45.2	55.8
RS		5956	9385	4170	4048	4997
	OAT-Ave	1999	2000	2001	2002	2003
1	47.5	525,520	498,260	427,335	419,907	414,272
2	50.5	525,520	498,260	427,335	431,686	414,272
3	54.4	531,590	498,260	441,952	447,697	414,272
4	57.8	551,521	498,260	455,907	461,241	423,961
5	64.5	591,534	560,247	483,922	488,431	457,527
6	70.0	624,557	612,279	507,043	510,871	485,228
7	73.0	642,067	639,868	519,302	522,770	499,917
8	73.4	644,508	643,716	521,012	524,429	501,965
9	70.5	627,599	617,073	509,173	512,939	487,781
10	62.5	579,519	541,316	475,510	480,267	447,448
11	53.5	526,193	498,260	438,174	444,030	414,272
12	47.3	525,520	498,260	427,335	419,030	414,272
Annual		6,895,649	6,604,061	5,634,001	5,663,300	5,375,184
Saving		0	4.2%	18.3%	17.9%	22.0%



Actual

		1999	2000	2001	2002	2003
1			535,857	432,927	407,814	437,404
2			515,918	425,579	452,909	432,936
3			491,363	468,849	453,045	377,497
4		568,348	531,438	452,266	462,904	409,249
5		585,433	534,830	475,282	464,696	457,163
6		629,963	640,547	537,614	530,341	
7		651,697		515,784	521,680	
8		668,859		518,968	531,073	
9		551,107		510,340	514,665	
10		564,445	529,207	482,942	445,511	
11		504,856	470,562	421,326	446,827	
12		534,978	475,144	424,391	409,202	
Annual		5,259,687		5,666,268	5,640,667	

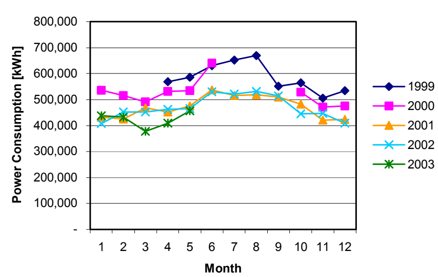


Figure 4: Example of regression based output by EModel

Another item to note are the OAT-Ave values in the EModel table. Those are the same values for the average curve in Figure 2.

3. Spreadsheet Analysis

While the kWh vs. OAT plots were useful in informing the question of persistence, the interpretation is somewhat technical and not widely accessible for the average building manager. Additionally, factoring in major base load changes and retrocommissioning measure impacts were difficult. As a result, most of the persistence analysis was conducted using spreadsheet calculations.

Appendix D is a copy of the analysis workbook containing all the spreadsheets used. The workbook has five analysis sheets, containing the table summaries and graphs used in the final report. Also included is one sheet for each site, containing the recommended measures with the raw data of measure-by-measure answers to the interview questions. The implemented measures are tagged and the estimated energy savings prediction from the retrocommissioning agent was summed into a formatted section of the sheet (Table 1).

Table 1: Example of spreadsheet format for average savings estimates

Shriners Hospital						Estimated Savings					
Measure # (Finding)	Complete	Planned	Incomplete			Elec usage [kWh]	Peak demand [kW]	Gas usage [therm]	Saved cost [$]	Imprementation cost [$]	Payback [year]
Study Totals											
			5		Not Completed	96,136	-	-	$13,728	$6,289	3.70
		2			Planned	138,771	-	-	$9,128	$10,285	2.47
	12				**Cx Report - Annual Savings for Completed Items**	**459,516**	**-**	**9,720**	**$35,226**	**$11,182**	**0.32**
					Cx Program Paybacks				**Cx Cost - Smud**	**$25,000**	**0.71**
									Cx Costs - Customer	**$3,300**	**0.09**
									Cx Costs - Total	**$28,300**	**0.80**
									Total Cx & Implementation Costs	**$39,482**	**1.12**
					Average Annual Savings from Monthly Bills	**503,907**		**5,101**	**$35,747**	**$11,182**	**0.31**
					Cx Program Paybacks				**Cx Cost - Smud**	**$25,000**	**0.70**
									Cx Costs - Customer	**$3,300**	**0.09**
									Cx Costs - Total	**$28,300**	**0.79**
									Total Cx & Implementation Costs	**$39,482**	**1.10**
					E-Model Average Annual Savings Estimate	**430,541**		**4,987**	**$30,863**	**$11,182**	**0.36**
					Cx Program Paybacks				**Cx Cost - Smud**	**$25,000**	**0.81**
									Cx Costs - Customer	**$3,300**	**0.11**
									Cx Costs - Total	**$28,300**	**0.92**
									Total Cx & Implementation Costs	**$39,482**	**1.28**
Smud Totals											
	18				Completed	1,855,130	-	13,853	$161,354	$233,617	1.447854
		0			Planned	-	-	-	$0	$0	
			5		Not Completed	328,944	-	29,204	$53,169	$19,486	0.366492
				2	Removed	111,017	-	-	$9,128	$10,285	1.126753

Annual average savings were also calculated from the actual billing history and the EModel normalized data. All three of the annual savings estimates were used to calculate simple payback benchmarks for each case. For the final report, only the retrocommissioning report and EModel average savings are used in the cost effectiveness and the predicted versus measured energy savings discussions.

The workbook is annotated with comments to document key assumptions. For example, every site sheet has a 'mouse over' comment for the "Cx Costs – Customer" value, documenting the building engineer's assumptions.

Also included on each site sheet are benchmark graphs, presenting year-by-year calculated benchmarks. None of these graphs were used in the main body of the final report. A selection of the graphs were used in the Appendix B Site Results.

a) Measure Persistence Analysis

As discussed in the main report, the measure persistence analysis relied heavily on interviews to determine the current status of the implemented retrocommissioning recommendations. After completion of the three phase interviews process, the Appendix D workbook was used to tally totals for the implemented, planned and incomplete measures. The table located in the "MeasurePersistSum" sheet, tracks the ID codes and status markers located in columns B thru E of each site sheet. The "MeasurePersistSum" then feeds the data for he final report tables that are located in the "MeasurePersistTables" sheet.

On each of the site sheets, a complete record of the recommended measures as presented by the retrocommissioning report is provide. In a addition, the raw data from the interview process are provided. The data is presented in differing font colors in order to separate information at each stage. Black fonts reflect data retrived from the retrocommissioning report or SMUD's Evaluation reports. Blue fonts reflect data obtained from the initial interviews and site visits. Red fonts reflect either the data changes or new information obtained in the second and third interview phases. Appendix C contains the raw interview notes, with some additional information not included in the Appendix D spreadsheet.

NOTE: The red colored values in the monthly energy consumption tables reflect data holes filled by estimates or calculated benchmarks that are directly based on estimated consumption values.

The question of the recommended measure's persistence state was manually finalized in column P. After reviewing the accumulated data story for each recommended measure, the measure was tagged as "Yes" for persisting, "No" for not persisting or "Evolved" for measures that didn't work but were not completely abandoned.

EVALUATION OF PERSISTENCE OF SAVINGS FROM SMUD RETROCOMMISSIONING PROGRAM

FINAL REPORT

SITE-BY-SITE ENERGY ANALYSIS RESULTS

APPENDIX B

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List of Tables

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Office1

The analysis of this site experienced difficulties isolating the increased energy use due to a computer data center expansion. The building's data center doubled in size to approximately 9000 ft^2 during 2000. We obtained some 15-minute interval data, but were unable to separate the base load associated with the data center. Another problem, was some missing monthly data for the period covering January 1999 through September 2000, precisely when the data center expansion occurred. This is the best baseline period, because the retrocommissioning report was delivered in April of 2000. As a work around we calculated two sets of annual savings estimates, one from a pre-commissioning baseline of 1998 and another from a post-commissioning baseline of 2000. The resulting average savings for 2001, 2002 and 2003 show an initial moderate savings in 2001 diminishing to none in 2003.

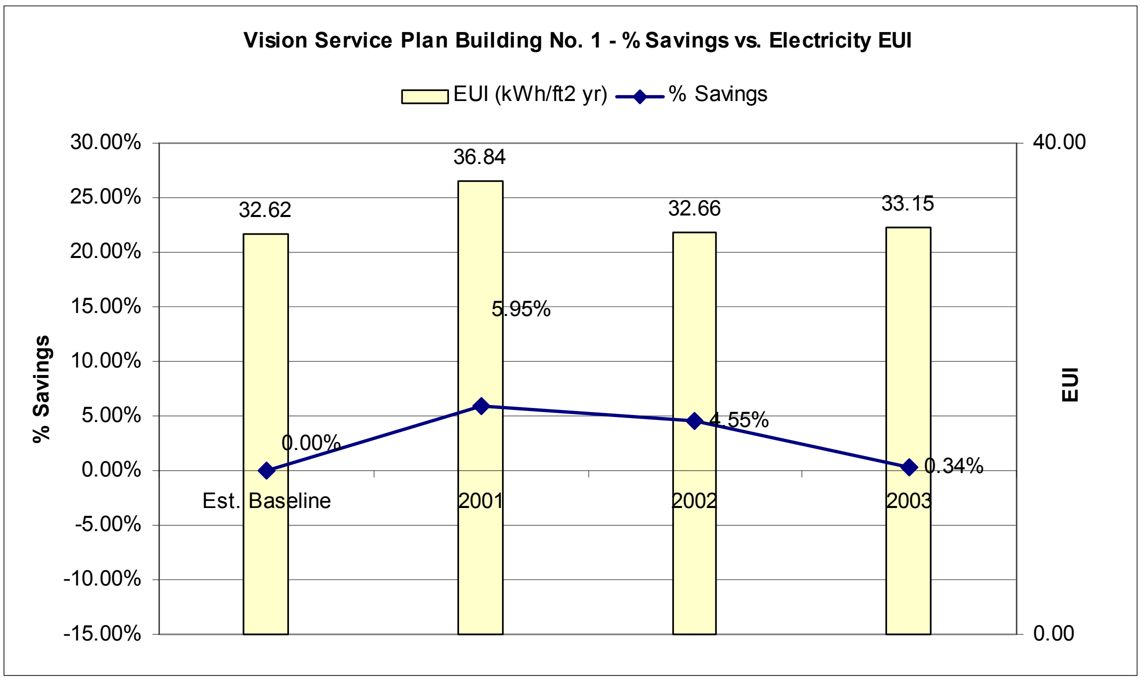

Figure 1: Electricity Savings for Office1

Available data for electricity usage analysis are monthly data of Jan 1998 to Dec 1998, and September 2000 to May 2003. Table 1 shows a summary of the available data. The annual usage has been increasing from 1998. Figure 2 plots annual trend of monthly electricity usage.

Table 1: Actual Monthly Electricity Usage for Office1

		1998	2000	2001	2002	2003
1		365,000		426,600	413,400	388,200
2		340,000		379,200	405,600	386,400
3		380,000		415,800	423,600	432,000
4		390,000		372,600	369,000	373,200
5		440,000		463,800	423,600	453,000
6		370,000		459,000	423,600	
7		430,000		405,600	477,600	
8		475,000		451,800	411,000	
9		450,000	499,800	385,200	404,400	
10		420,000	442,200	379,800	383,400	
11		390,000	468,600	401,400	445,200	
12		395,000	440,400	367,800	394,200	
Annual		4,845,000		4,908,600	4,974,600	

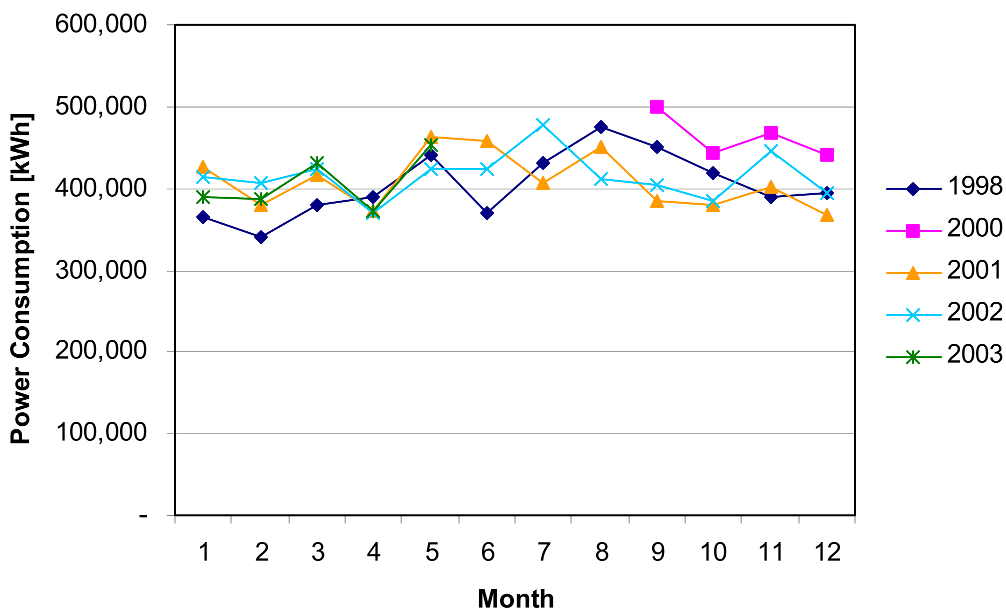

Figure 2: Actual Monthly Electricity Usage for Office1

Figure 3 shows the E-Model plot of whole building power (WBP) versus outside air temperature (OAT) for Office1.

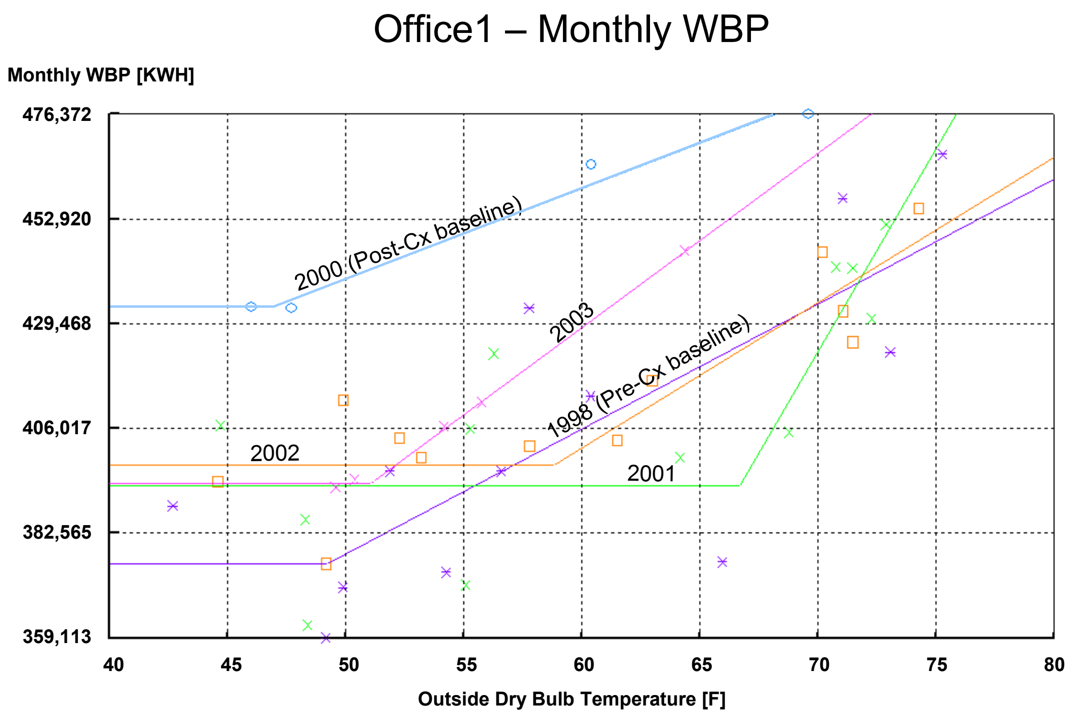

Figure 3: E-Model - kWh vs. OAT Plot for Office1

Table 2 and Figure 4 show the EModel regression model results. The baseline year corrections calculated by the Appendix D spreadsheet is reflected in Figure 1.

Table 2: E-Model - Normalized Monthly Electricity Usage for Office1

		1998	2000	2001	2002	2003
Ycp		373000.56	450400	391385.24	408818.18	387408.7
Xcp		49.872	60.632	68.388	71.924	52.856
RS		3135.5654	5508.4746	14761.638	28948.577	6048.299

	OAT-1998	1998	2000	2001	2002	2003
1	49.2	373,001	450,400	391,385	408,818	387,409
2	49.9	373,167	450,400	391,385	408,818	387,409
3	54.3	386,935	450,400	391,385	408,818	396,240
4	56.6	394,233	450,400	391,385	408,818	410,316
5	57.8	397,809	450,400	391,385	408,818	417,214
6	66.0	423,602	480,025	391,385	408,818	466,968
7	73.1	445,783	518,991	460,704	442,395	509,753
8	75.3	452,803	531,323	493,751	507,202	523,293
9	71.1	439,489	507,934	431,074	408,818	497,613
10	60.4	406,153	450,400	391,385	408,818	433,310
11	51.9	379,401	450,400	391,385	408,818	387,409
12	42.7	373,001	450,400	391,385	408,818	387,409
Annual		4,845,376	5,641,472	4907996.5	5037778.9	5204341
Saving		0.0%	-16.4%	-1.3%	-4.0%	-7.4%

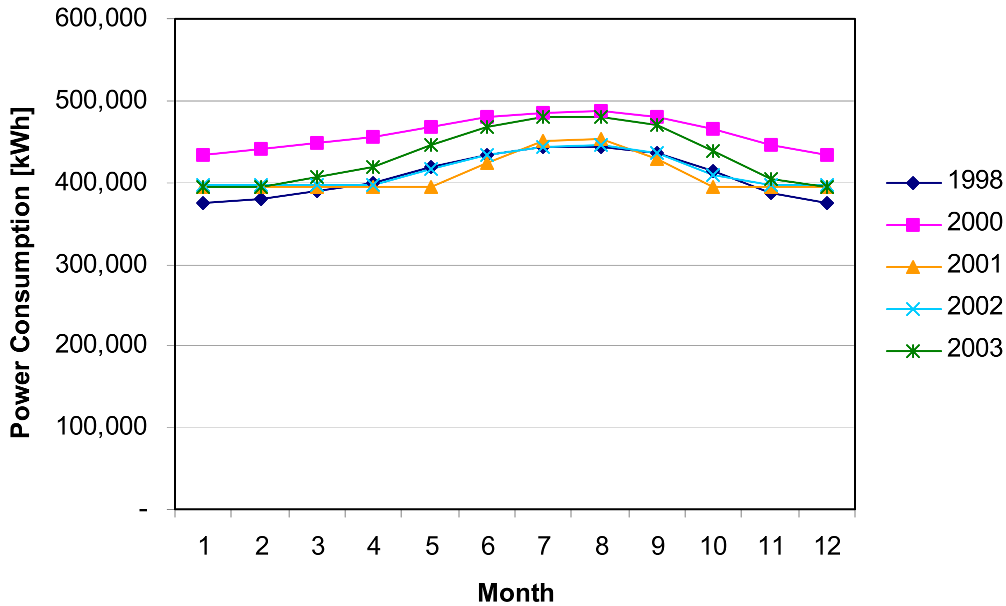

Figure 4: E-Model - Normalized Monthly Electricity Usage for Office1

Office2

The available metering data at this site included monthly data for electricity and gas, as well as EnerLink based 15-minute interval data for the whole building electricity and the chiller plant. The retrocommissioning report recommended 8 corrective measures and the facility implemented 3. One implemented recommendation was a capital intensive project to replace two chillers. Since this measure doesn't fit into the retrocommissioning low cost scope of this study, we removed the energy savings due to the chiller upgrade using 15-minute interval sub metering data.

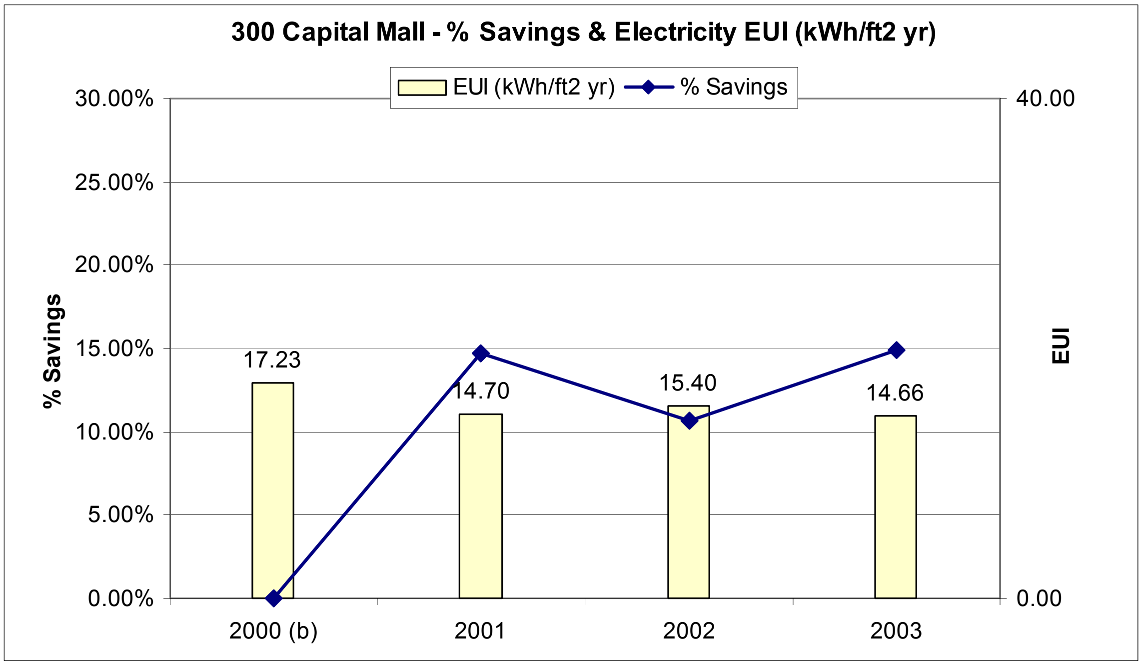

Figure 5: Electricity Savings for Office2

The annual electricity usage at Office2 has decreased after retrocommissioning. Compared against a 1999 baseline, the annual usage decreased 14.7% in 2001, 10.6% in 2002, and 14.7% in 2003 (Figure 5). With inclusion of natural gas consumption (Figure 6), the whole building savings reduces slightly in 2001 and 2002, but recovered in 2003 (Figure 7).

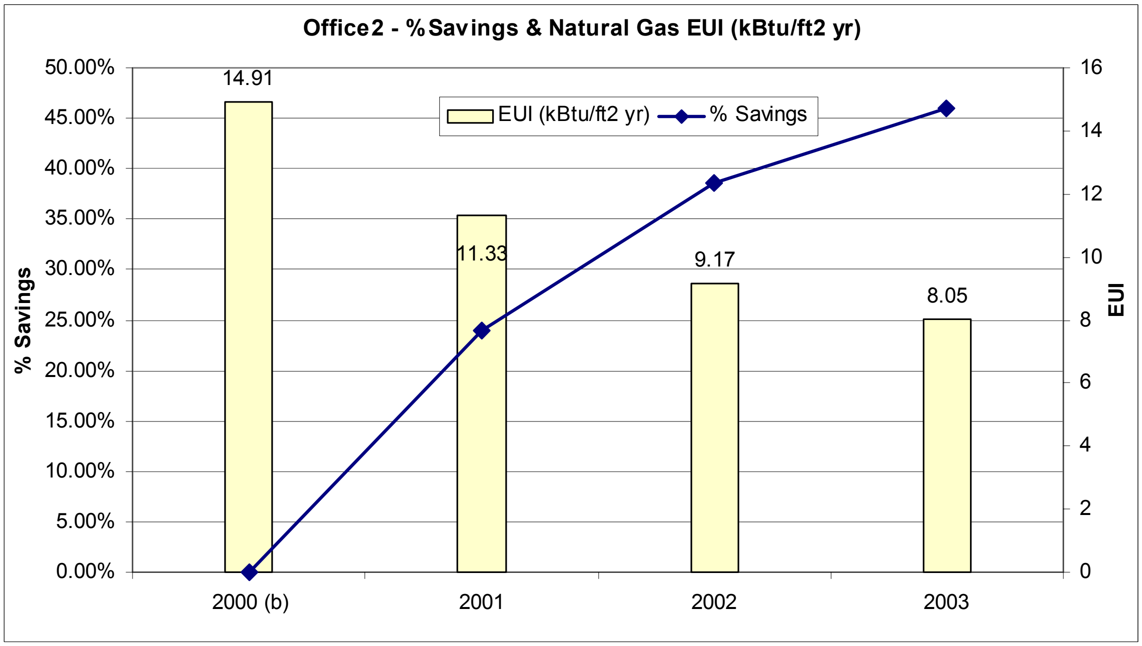

Figure 6: Natural Gas Savings for Office2

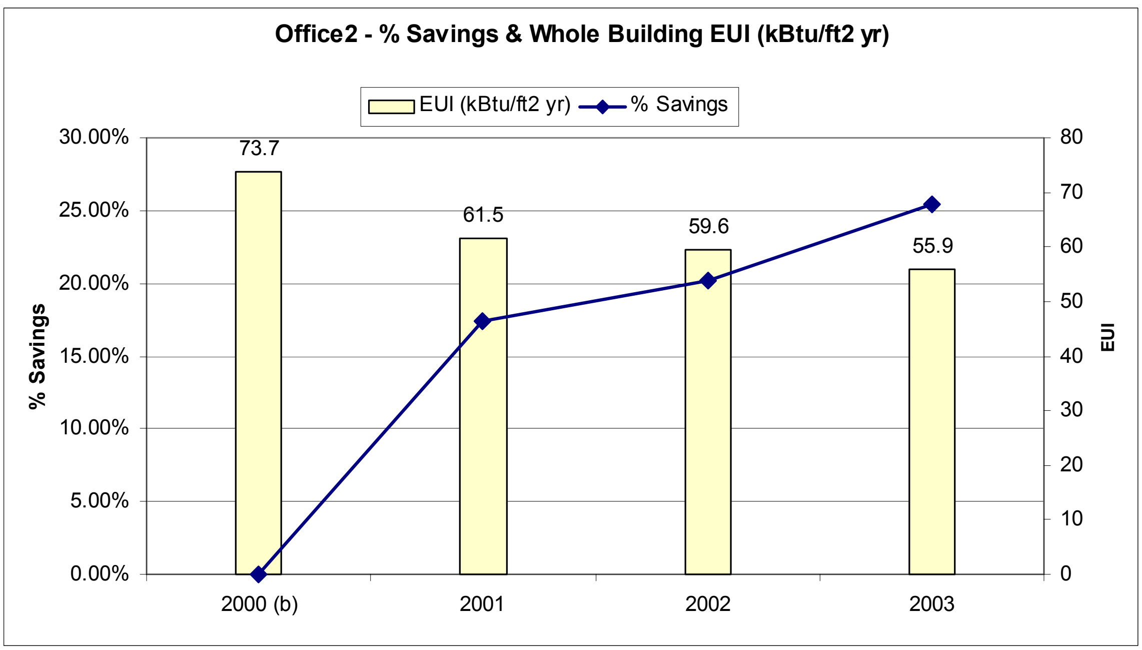

Figure 7: Whole Building (Elec. & Gas) Savings for Office2

It is unlikely that the two recommended measures are responsible for all the savings. This facility is very active with maintenance and systems improvements and our interviews probably did not capture all the upgrades performed after the 1999 retrocommissioning process. However, the chief engineer was vocal in pointing out how much they learned from the commissioning agent and credits the event as having an effect on their building maintenance and operations.

Table 3 and Figure 8shows a summary of the available electrical consumption data for Office2.

Table 3: Actual Monthly Electricity Usage for Office2

		1999	2000	2001	2002	2003
1			535,857	432,927	407,814	437,404
2			515,918	425,579	452,909	432,936
3			491,363	468,849	453,045	377,497
4		568,348	531,438	452,266	462,904	409,249
5		585,433	534,830	475,282	464,696	457,163
6		629,963	640,547	537,614	530,341	
7		651,697		515,784	521,680	
8		668,859		518,968	531,073	
9		551,107		510,340	514,665	
10		564,445	529,207	482,942	445,511	
11		504,856	470,562	421,326	446,827	
12		534,978	475,144	424,391	409,202	
Annual		5,259,687		5,666,268	5,640,667	

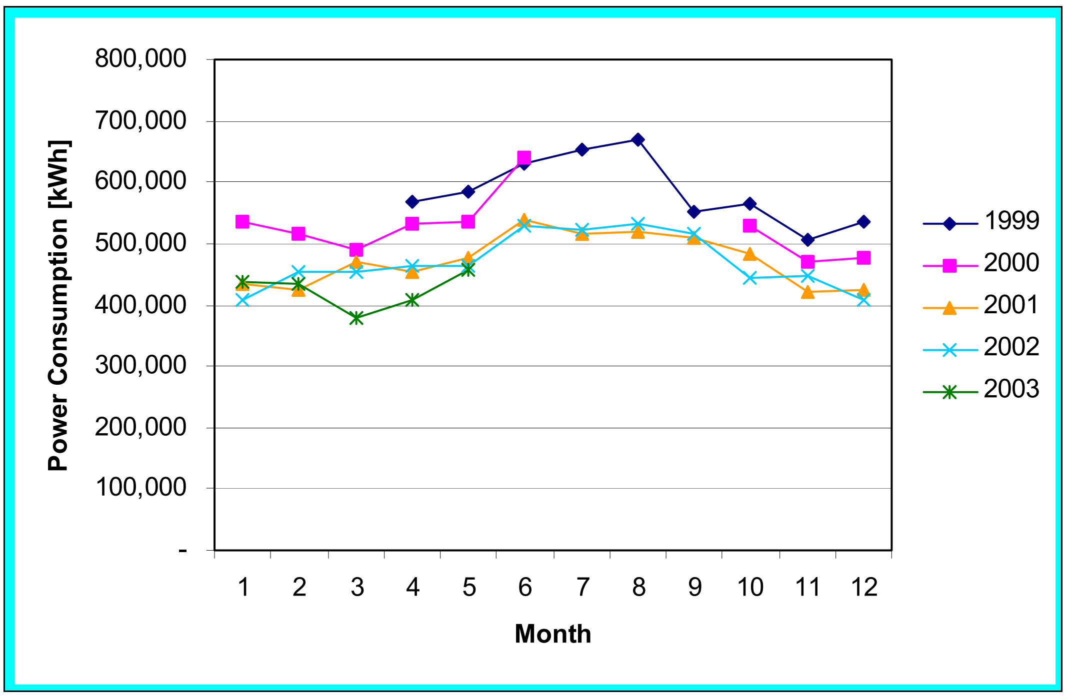

Figure 8: Actual Monthly Electricity Usage for Office2

Table 4 and Figure 9shows a summary of the available natural gas consumption data for Office2.

Table 4: Actual Monthly Natural Gas Usage for Office2

		1999	2000	2001	2002	2003
1			535,857	432,927	407,814	437,404
2			515,918	425,579	452,909	432,936
3			491,363	468,849	453,045	377,497
4		568,348	531,438	452,266	462,904	409,249
5		585,433	534,830	475,282	464,696	457,163
6		629,963	640,547	537,614	530,341	
7		651,697		515,784	521,680	
8		668,859		518,968	531,073	
9		551,107		510,340	514,665	
10		564,445	529,207	482,942	445,511	
11		504,856	470,562	421,326	446,827	
12		534,978	475,144	424,391	409,202	
Annual		5,259,687		5,666,268	5,640,667	

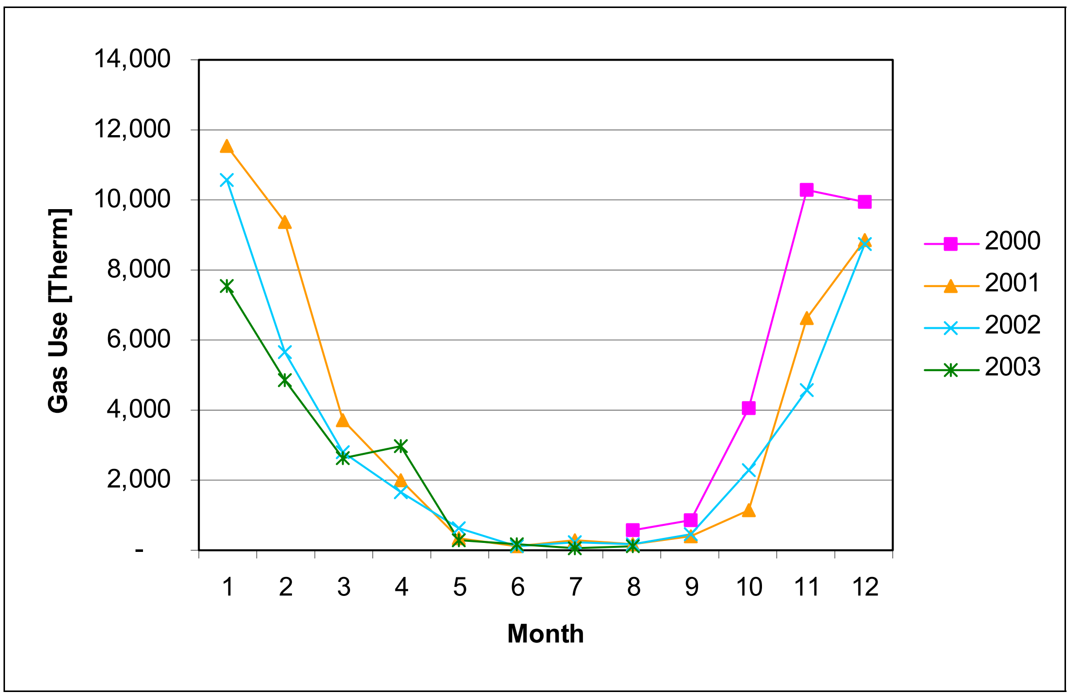

Figure 9: Actual Monthly Natural Gas Usage for Office2

Figure 10 shows the E-Model plot of whole building power (WBP) versus outside air temperature (OAT) and Figure 11 shows the Natural Gas versus OAT for Office2.

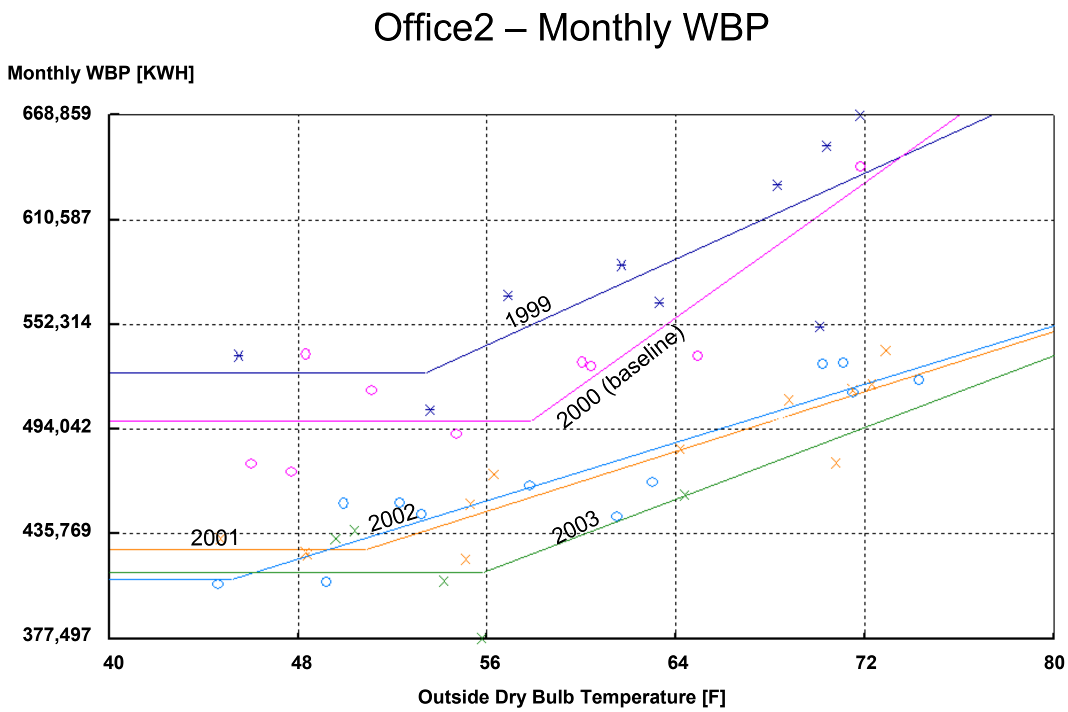

Figure 10: E-Model - kWh vs. OAT Plot for Office2

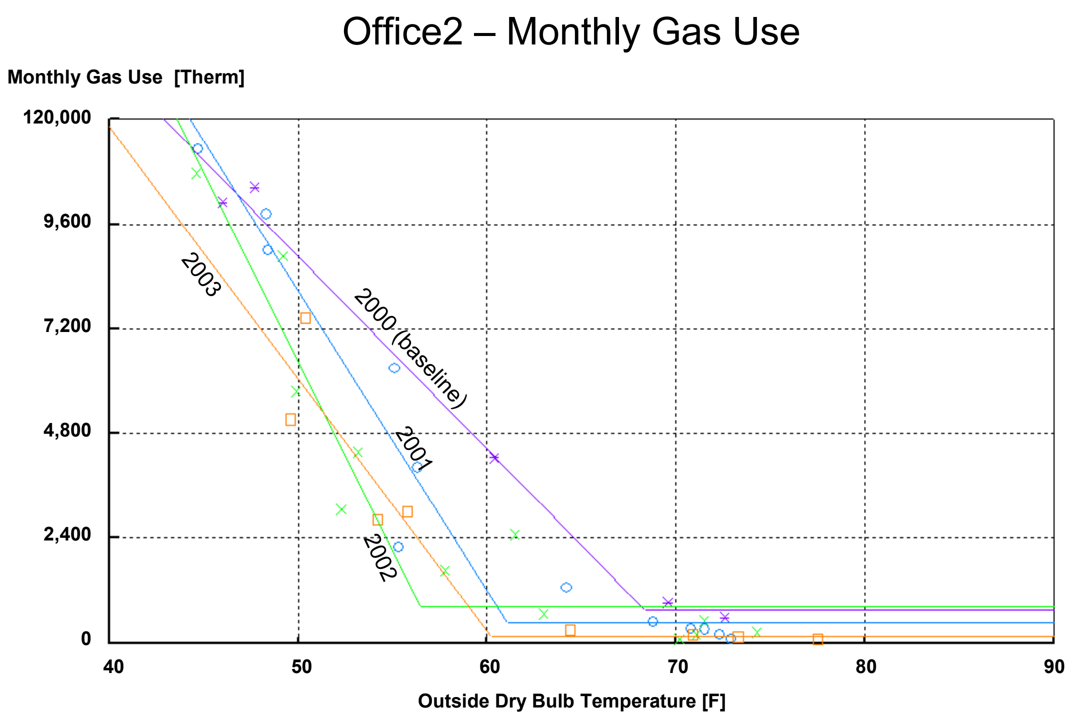

Figure 11: E-Model - Natural Gas vs. OAT for Office2

Table 5 and Figure 12show the EModel electricity regression model results for Office2.

Table 5: E-Model - Normalized Monthly Electricity Usage for Office2

		1999	2000 (b)	2001	2002	2003
Ycp		525520	498260	427335	410399	414272
Xcp		53.4	57.9	50.9	45.2	55.8
RS		5956	9385	4170	4048	4997
	OAT-Ave	1999	2000	2001	2002	2003
1	47.50	525,520	498,260	427,335	419,907	414,272
2	50.50	525,520	498,260	427,335	431,686	414,272
3	54.40	531,590	498,260	441,952	447,697	414,272
4	57.80	551,521	498,260	455,907	461,241	423,961
5	64.50	591,534	560,247	483,922	488,431	457,527
6	70.00	624,557	612,279	507,043	510,871	485,228
7	73.00	642,067	639,868	519,302	522,770	499,917
8	73.40	644,508	643,716	521,012	524,429	501,965
9	70.50	627,599	617,073	509,173	512,939	487,781
10	62.50	579,519	541,316	475,510	480,267	447,448
11	53.50	526,193	498,260	438,174	444,030	414,272
12	47.3	525,520	498,260	427,335	419,030	414,272
Annual		6,895,648	6,604,059	5,634,000	5,663,298	5,375,187
Saving		-4.42%	0.00%	14.69%	14.25%	18.61%

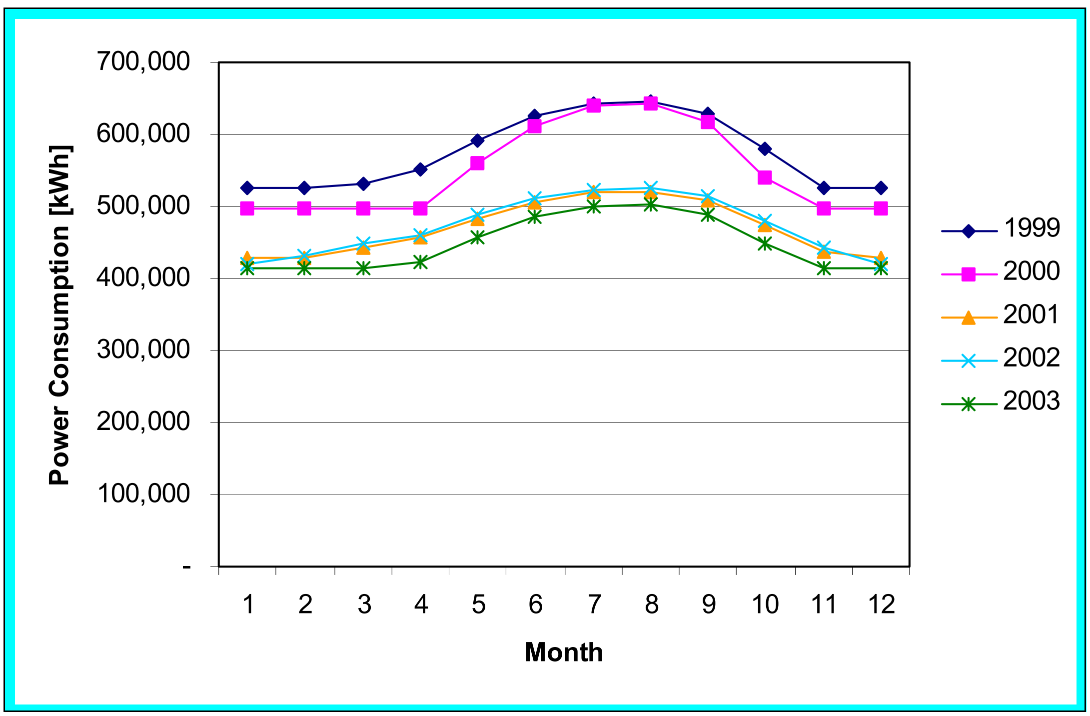

Figure 12: E-Model - Normalized Monthly Electricity Usage for Office2

Table 6 and Figure 13 show the EModel natural gas regression model results for Office2.

Table 6: E-Model - Normalized Monthly Natural Gas Usage for Office2

		1999	2000 (b)	2001	2002	2003
Ycp			761.261	452.7	822.3	154.0
Xcp			68.344	61.1	56.5	60.2
RS			-441.1508	-686.4	-866.4	-577.6
	OAT-Ave	1999	2000 (b)	2001	2002	2003
1	47.50		9,938	9,728	8,566	7,466
2	50.50		8,654	7,731	6,044	5,785
3	54.40		6,909	5,015	2,617	3,500
4	57.80		5,433	2,719	822	1,567
5	64.50		2,469	453	822	154
6	70.00		761	453	822	154
7	73.00		761	453	822	154
8	73.40		761	453	822	154
9	70.50		761	453	822	154
10	62.50		3,359	453	822	154
11	53.50		7,308	5,637	3,402	4,023
12	47.3		10,033	9,877	8,753	7,591
Annual			57,147	43,424	35,137	30,857
Saving			0.00%	24.01%	38.51%	46.00%

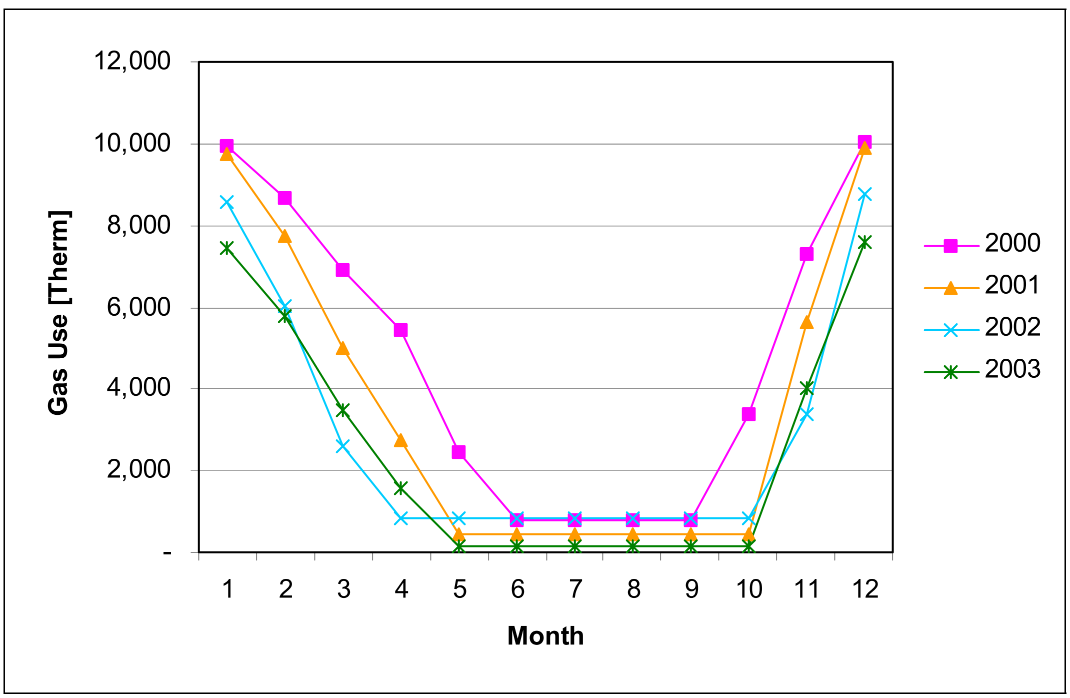

Figure 13: E-Model - Normalized Monthly Natural Gas Usage for Office2

Lab1

The retrocommissioning activities at this site showed very good success. The site contact reports that additional measures, beyond the retrocommissioning recommendations, were developed and implemented by their operators. He feels the additional measures would not have been implemented if not for the retrocommissioning effort. This study did not have the necessary data to separate any savings associated with the post-retrocommissioning measures that were developed by the facility staff.

The Retrocommissioning report recommended 8 measures and 4 were implemented. This count includes 4 measures identified as capital intensive by the retrocommissioning report, but were implemented at low cost by the site. One of the capital intensive measures was implemented partially through BAS programming, there are no plans to complete the hardware installation component of the recommendation.

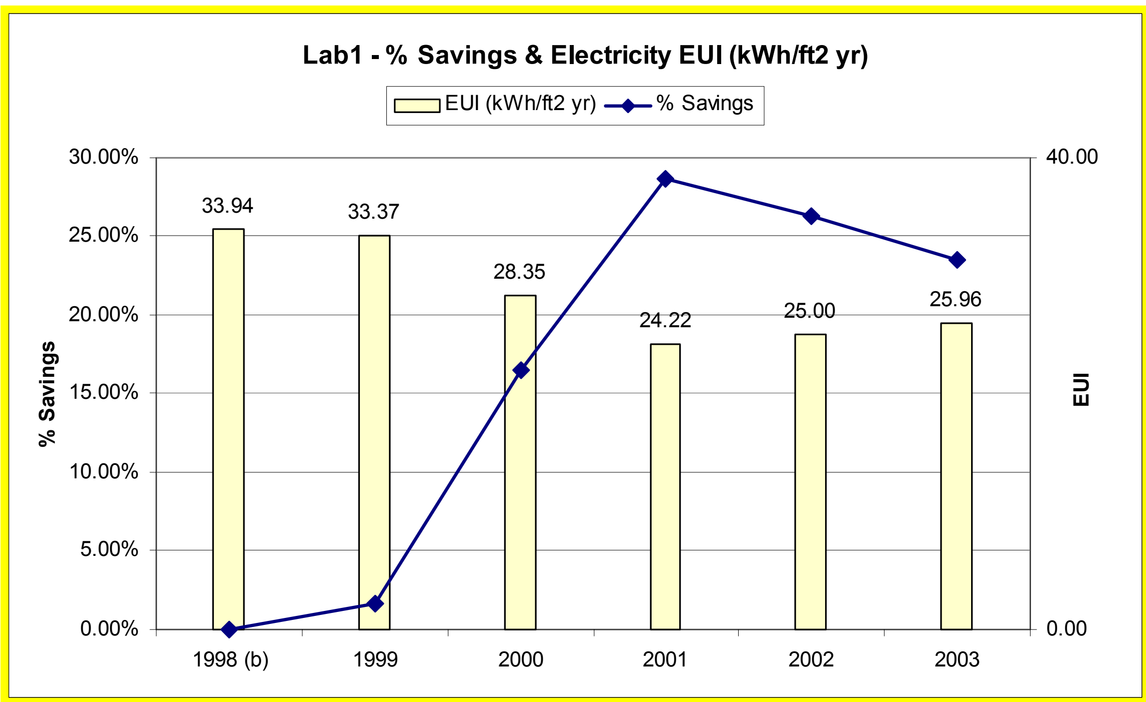

Figure 14: Electricity Savings for Lab1

Table 7 and Figure 15show a summary of the available electrical consumption data.

Table 7: Actual Monthly Electricity Usage for Lab1

		1997	1998	1999	2000	2001	2002	2003
1		189,600	252,400	220,400	211,600	183,600	180,000	172,800
2		224,800	228,400	208,800	202,000	158,800	153,200	163,600
3		234,400	236,800	217,600	218,400	167,200	174,000	188,000
4		253,600	262,800	242,400	228,000	183,600	166,800	165,200
5		292,000	260,000	256,800	231,200	218,800	214,800	218,000
6		254,800	275,600	323,600	273,200	202,800	214,800	
7		284,800	336,000	280,400	236,000	190,000	206,000	
8		294,800	312,800	330,400	218,000	218,800	227,600	
9		259,600	264,800	315,600	238,400	193,200	202,000	
10		250,800	258,000	231,200	180,400	164,800	170,000	
11		244,000	221,200	228,400	184,400	172,800	180,000	
12		238,400	220,800	213,600	192,000	162,800	164,440	
Annual		3,021,600	3,129,600	3,069,200	2,613,600	2,217,200	2,253,640	

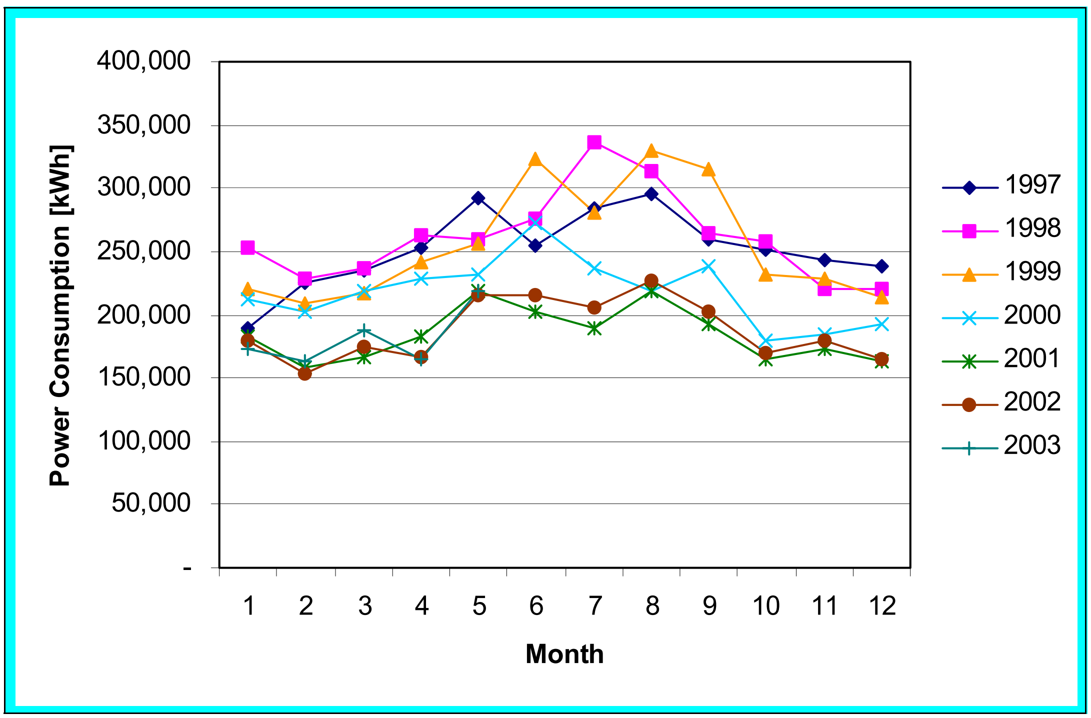

Figure 15: Actual Monthly Electricity Usage for Lab1

Figure 16 shows the E-Model plot of whole building power (WBP) versus outside air temperature (OAT) for Lab1.

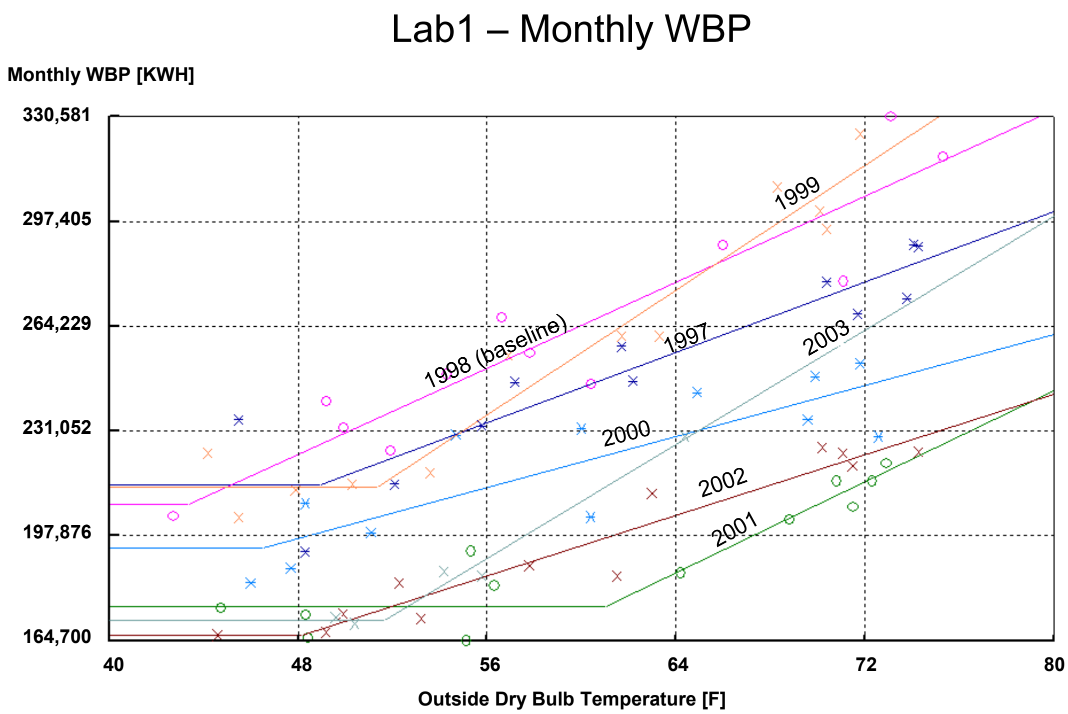

Figure 16: E-Model - kWh vs. OAT Plot for Lab1

Table 8 and Figure 17 show the EModel regression model results for Lab1.

Table 8: E-Model - Normalized Monthly Electricity Usage for

		1997	1998	1999	2000	2001	2002	2003
Ycp		213906	207940	213319	194030	175483	166185	171082
Xcp		48.956	43.352	51.376	46.532	61.056	48.164	51.672
RS		2793	3398	4932	2023	3607	2401	4515
	OAT-Ave	1997	1998	1999	2000	2001	2002	2003
1	47.5	213,906	222,183	213,319	196,076	175,483	166,185	171,082
2	50.5	218,087	232,072	213,319	201,964	175,483	171,680	171,082
3	54.4	229,135	245,514	228,277	209,968	175,483	181,177	183,440
4	57.8	238,480	256,885	244,780	216,739	175,483	189,209	198,549
5	64.5	257,241	279,713	277,910	230,332	187,808	205,335	228,881
6	70.0	272,724	298,553	305,252	241,550	207,807	218,644	253,914
7	73.0	280,933	308,543	319,750	247,498	218,411	225,700	267,187
8	73.4	282,078	309,936	321,772	248,328	219,890	226,685	269,038
9	70.5	274,150	300,289	307,772	242,584	209,649	219,870	256,220
10	62.5	251,607	272,859	267,962	226,250	180,532	200,493	219,773
11	53.5	226,605	242,435	223,809	208,135	175,483	179,002	179,349
12	47.3	213,906	221,447	213,319	195,637	175,483	166,185	171,082
Annual		2,958,853	3,190,428	3,137,241	2,665,061	2,276,997	2,350,165	2,569,599
Saving		7.3%	0.0%	1.7%	16.5%	28.6%	26.3%	19.5%

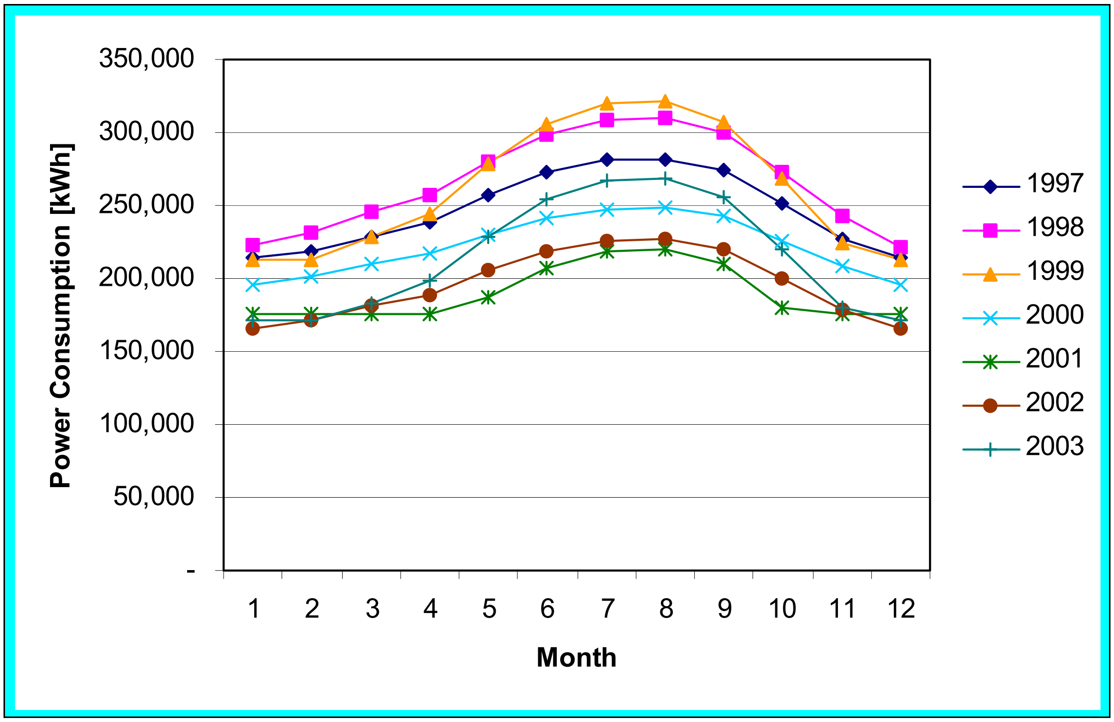

Figure 17: E-Model - Normalized Monthly Electricity Usage for

Hospital1

The billing history shows an average of 4.37% electricity savings from a 1999 baseline year. While the percentage savings versus the baseline is small, the absolute value electricity was significant, ranging from 390,471 to 766,445 kWh per year. The retrocommissioning report included a total of 19 recommended measures, of which 12 are implemented. Also included in the retrocommissioning report are 6 capital intensive measures (none were implemented), which this study did not examine.

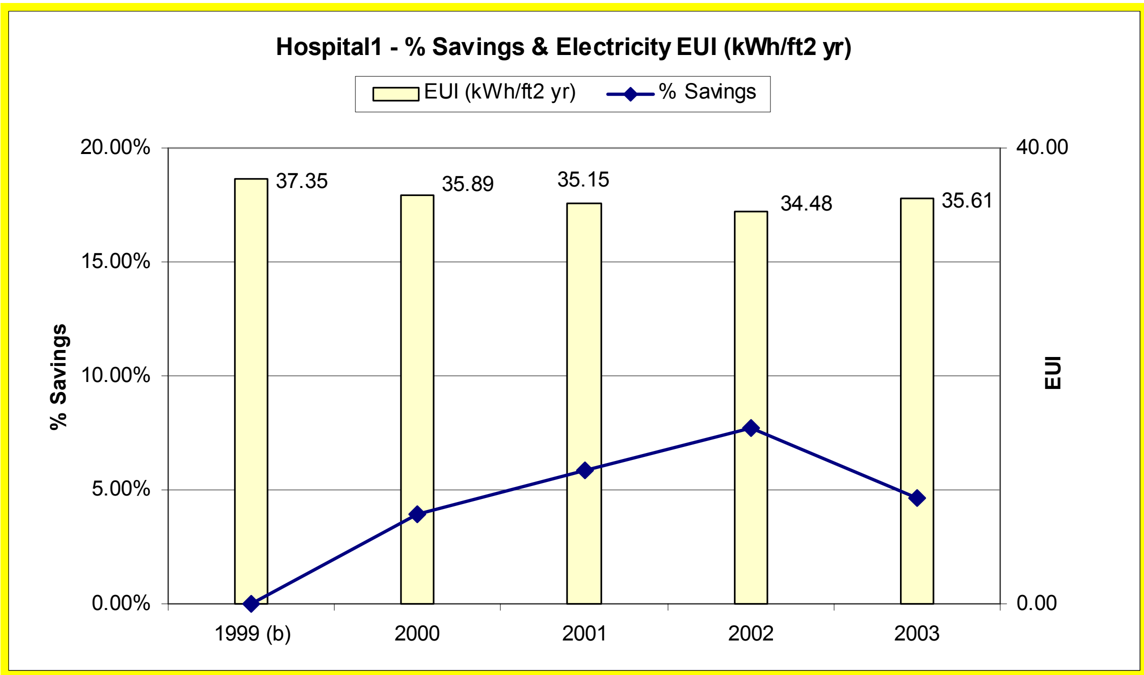

Figure 18: Electricity Savings for Hospital1

Adding natural gas consumption (Figure 19) changes the whole building energy savings significantly for 2002 (Figure 20). Natural gas use for 2002 increased by 9.8 %, off setting the 2002 electrical energy savings. The facility recently reduced the steam system pressure 100psi to 65psi, in an effort to find some natural gas savings.

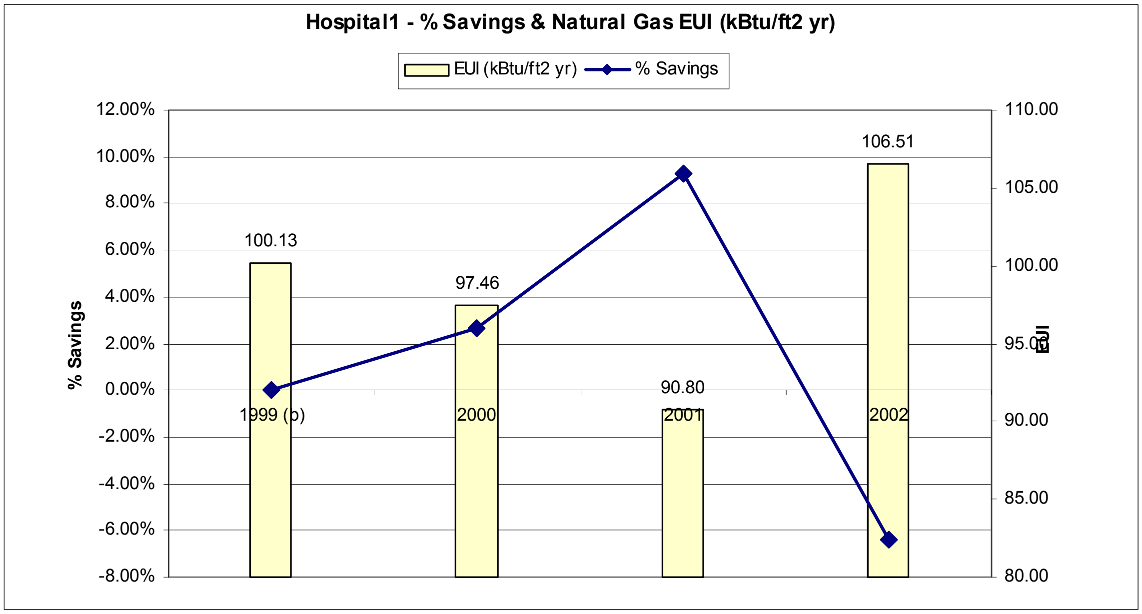

Figure 19: Natural Gas Savings for Hospital1

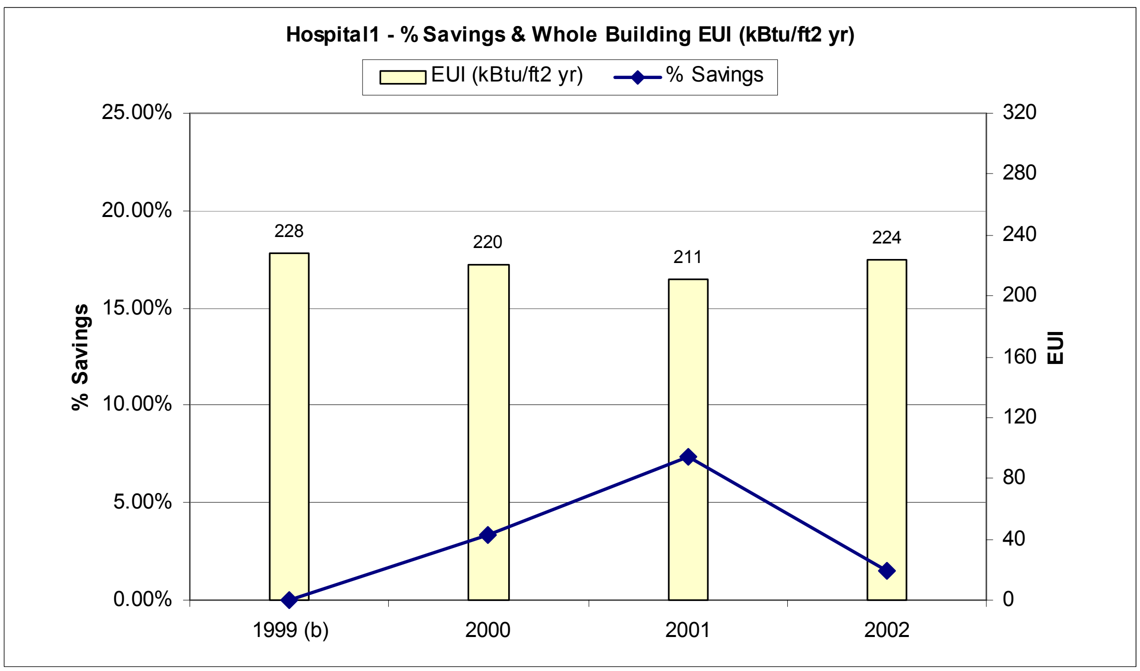

Figure 20: Whole Building (Elec. & Gas) Savings for Hospital1

Reasons for the apparent reduction in savings are difficult to isolate, but much of the increased 2002 energy use likely comes from a new research laboratory addition (approx. 24,000 ft2) that was completed that year. All the EUI values for 2002 and later include the new conditioned floor area due to the new laboratory wing.

Table 9and Figure 21shows a summary of the available electricity consumption data for Hospital1.

Table 9: Actual Monthly Electricity Usage for Hospital1

		1998	1999	2000	2001	2002	2003
1		854,800	776,000	788,400	809,600	808,400	796,800
2		806,400	768,400	777,200	679,200	727,600	750,000
3		760,800	793,600	779,200	698,000	781,600	824,800
4		844,400	827,200	796,800	762,400	754,000	708,800
5		823,600	842,400	838,400	872,800	940,000	884,000
6		852,400	998,400	987,200	867,200	882,800	
7		983,200	859,200	886,400	782,000	885,200	
8		941,200	952,000	867,200	851,200	972,000	
9		812,000	933,200	914,400	809,600	869,600	
10		844,400	799,600	778,000	742,400	768,400	
11		750,400	815,200	761,600	762,400	812,400	
12		834,800	806,800	781,600	755,200	758,800	
Annual		10,108,400	10,172,000	9,956,400	9,392,000	9,960,800	

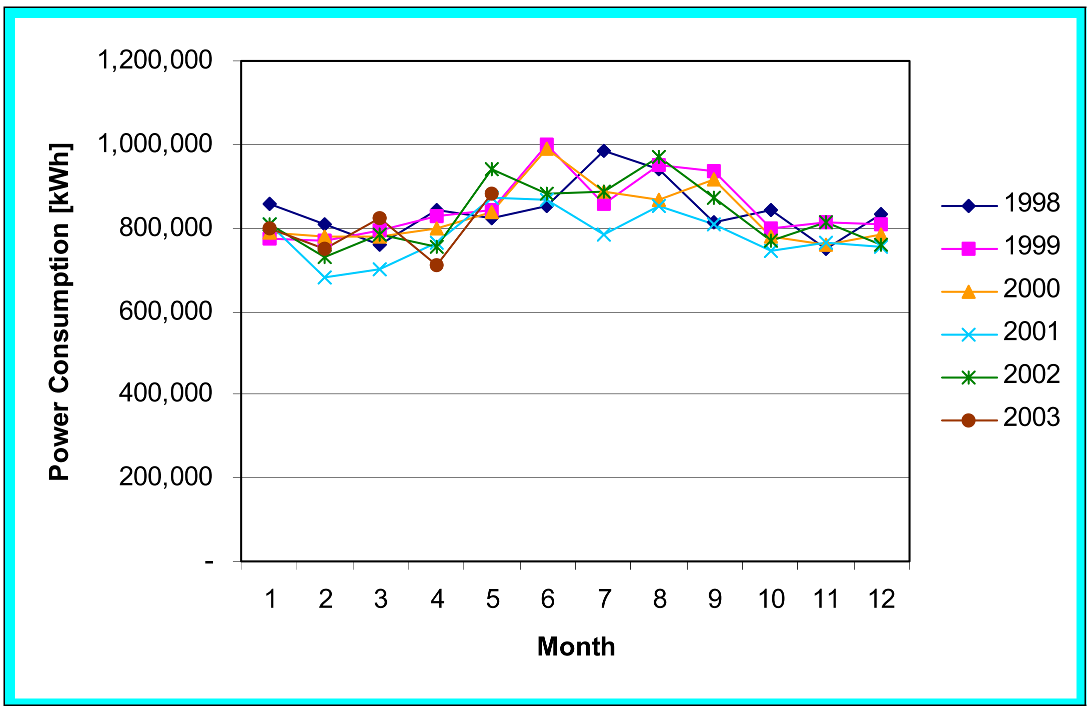

Figure 21: Actual Monthly Electricity Usage for Hospital1

Table 10and Figure 22 shows a summary of the available natural gas consumption data for Hospital1.

Table 10: Actual Monthly Natural Gas Usage for Hospital1

		1998	1999	2000	2001	2002	2003
1		27,984	32,903	31,622	28,748	39,660	35,773
2		26,908	26,756	27,284	24,349	32,280	29,271
3		23,894	25,441	24,523	18,327	31,537	
4		21,472	20,039	22,063	19,169	28,125	
5		22,142	22,988	24,449	17,505	22,086	
6		20,237	19,972	20,960	17,399	18,762	
7		18,045	20,119	22,227	17,908	19,822	
8		14,891	17,949	19,884	15,191	18,291	
9		16,004	20,161	19,149	16,296	19,198	
10		15,232	18,713	19,239	16,850	24,028	
11		19,904	24,630	26,096	21,268	27,099	
12		31,423	27,439	23,947	32,187	34,511	
Annual		258,136	277,110	281,443	245,197	315,399	

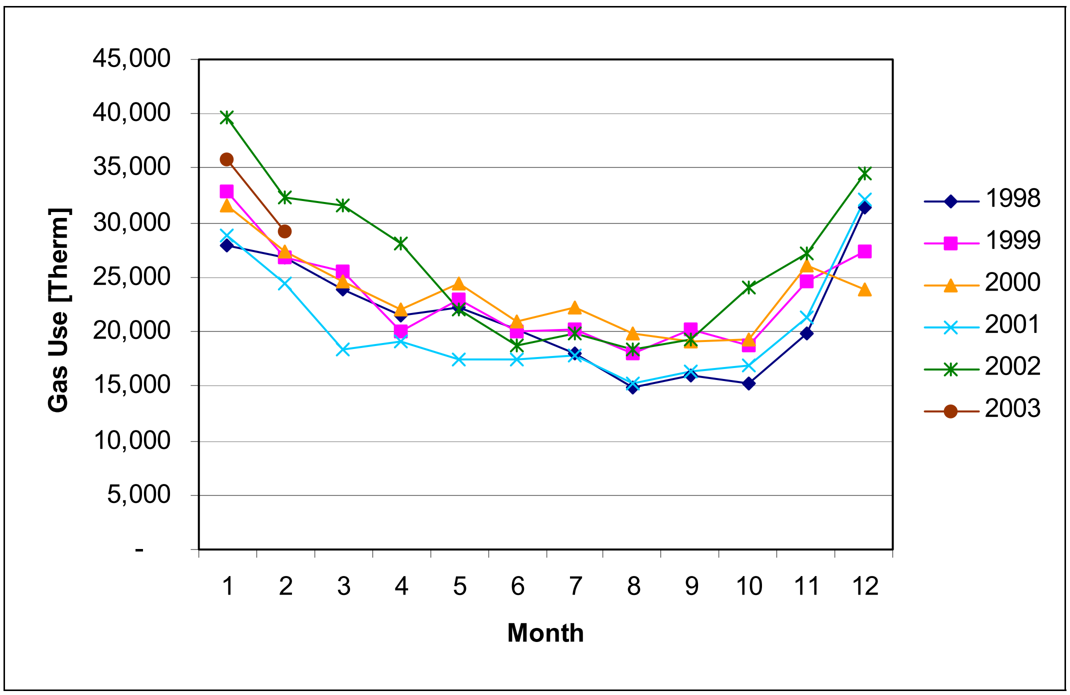

Figure 22: Actual Monthly Natural Gas Usage for Hospital1

Figure 23 shows the E-Model plot of whole building power (WBP) versus outside air temperature (OAT) and Figure 24 shows the Natural Gas versus OAT for Hospital1.

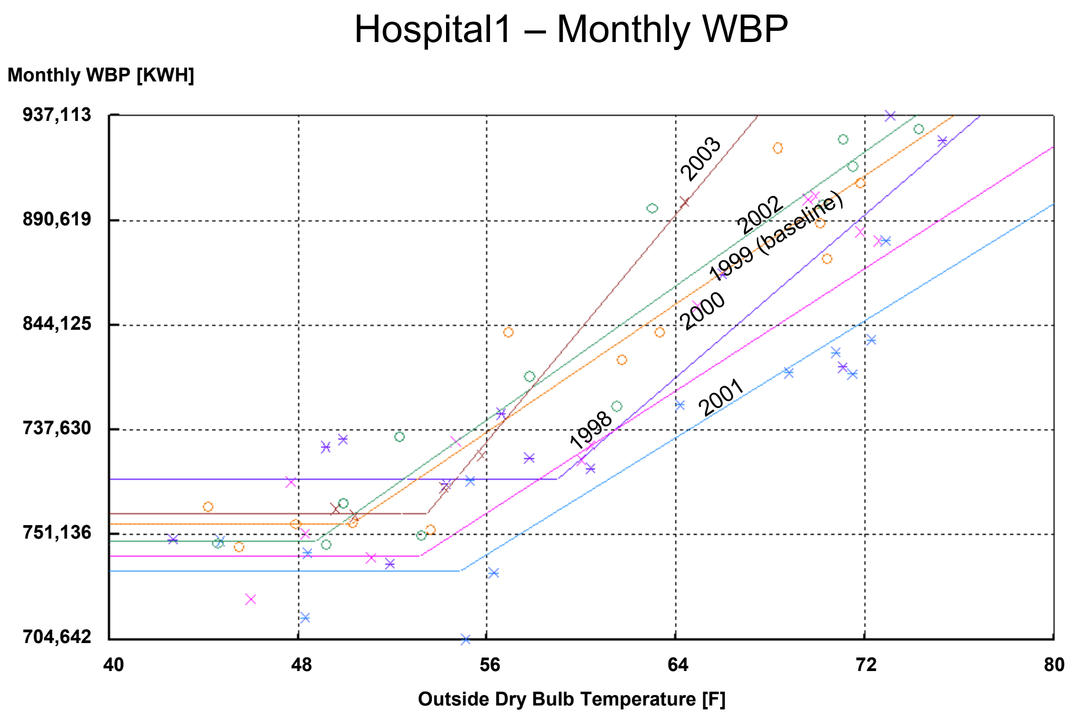

Figure 23: E-Model - kWh vs. OAT Plot for Hospital1

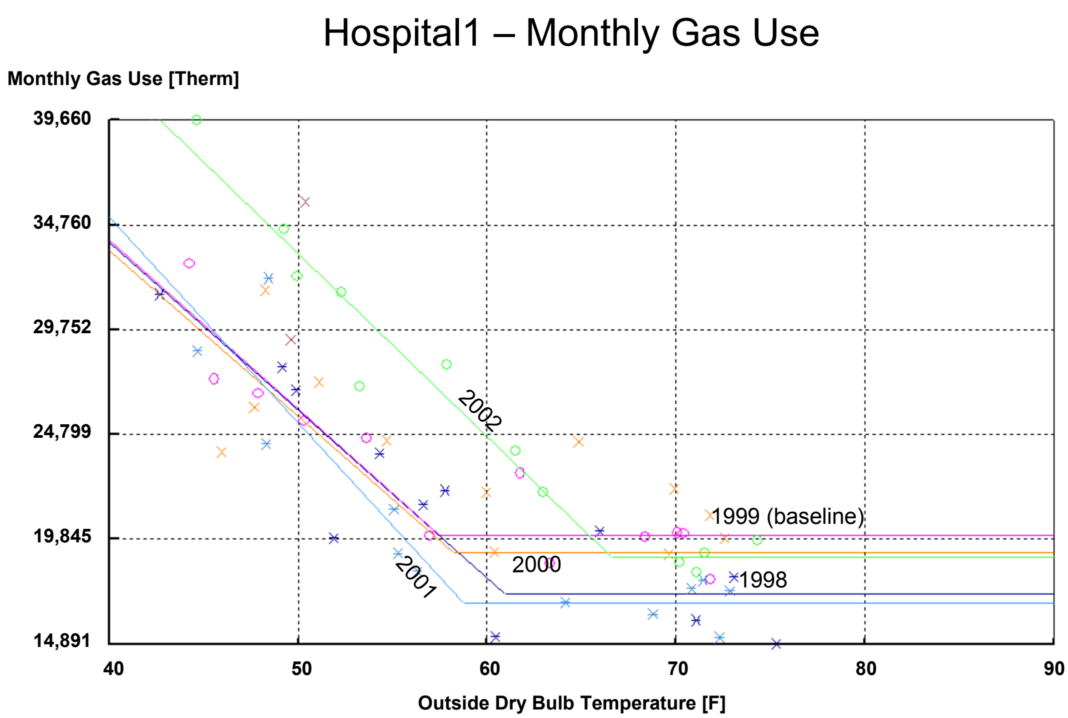

Figure 24: E-Model - Natural Gas vs. OAT for Hospital1

Table 11 and Figure 25 show the EModel regression model results for Hospital1.

Table 11: E-Model - Normalized Monthly Electricity Usage for Hospital1

		1998	1999	2000	2001	2002	2003
Ycp		819166	797515	777971	744085	778278	762698
Xcp		70.1	59.1	59.3	63.9	56.5	54.0
RS		30105	11806	11474	12431	8394	12289
	OAT-Ave	1998	1999	2000	2001	2002	2003
1	47.5	819,166	797,515	777,971	744,085	778,278	762,698
2	50.5	819,166	797,515	777,971	744,085	778,278	762,698
3	54.4	819,166	797,515	777,971	744,085	778,278	767,233
4	57.8	819,166	797,515	777,971	744,085	788,982	808,354
5	64.5	819,166	860,898	837,324	751,503	845,366	890,907
6	70.0	819,166	926,352	900,936	820,421	891,901	959,038
7	73.0	905,641	961,057	934,665	856,964	916,575	995,164
8	73.4	917,982	965,897	939,369	862,060	920,016	1,000,202
9	70.5	832,521	932,382	906,797	826,771	896,188	965,316
10	62.5	819,166	837,084	814,179	744,085	828,435	866,119
11	53.5	819,166	797,515	777,971	744,085	778,278	762,698
12	47.3	819,166	797,515	777,971	744,085	778,278	762,698
Annual		10,028,635	10,268,758	10,001,099	9326314.898	9978853.376	10303125
Saving		0.0%	-2.4%	0.3%	7.0%	0.5%	-2.7%

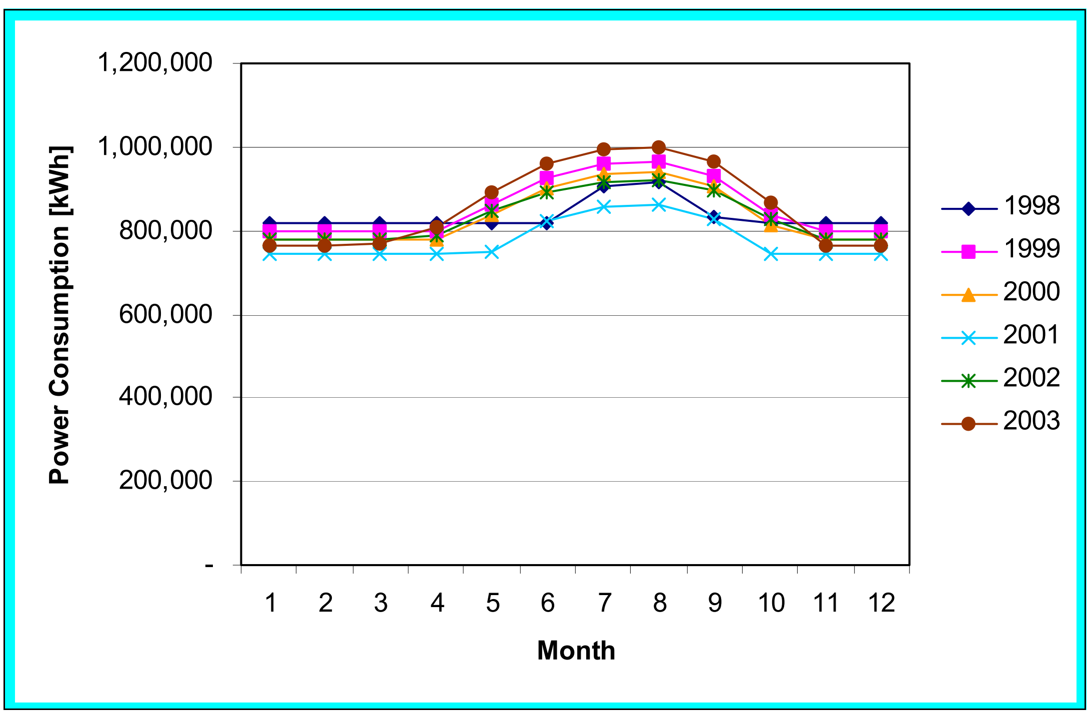

Figure 25: E-Model - Normalized Monthly Electricity Usage for Hospital1

Table 12 and Figure 26 show the EModel regression model results for Hospital1.

Table 12: E-Model - Normalized Monthly Natural Gas Usage for Hospital1

		1998	1999	2000	2001	2002	2003
Ycp		17230	20001	19185	16836	19000	
Xcp		61.0	57.5	58.2	58.8	66.6	
RS		-793	-800	-784	-970	-865	
	OAT-Ave	1998	1999	2000	2001	2002	2003
1	47.5	27,866	27,948	27,549	27,732	35,465	
2	50.5	25,560	25,620	25,266	24,908	32,950	
3	54.4	22,425	22,456	22,164	21,070	29,530	
4	57.8	19,773	20,001	19,540	17,823	26,637	
5	64.5	17,230	20,001	19,185	16,836	20,829	
6	70.0	17,230	20,001	19,185	16,836	19,000	
7	73.0	17,230	20,001	19,185	16,836	19,000	
8	73.4	17,230	20,001	19,185	16,836	19,000	
9	70.5	17,230	20,001	19,185	16,836	19,000	
10	62.5	17,230	20,001	19,185	16,836	22,573	
11	53.5	23,143	23,181	22,875	21,949	30,313	
12	47.3	28,038	28,121	27,718	27,942	35,653	
Annual		250,184	267,336	260,222	242439.1453	309949.8094	
Saving		0.0%	-6.9%	-4.0%	3.1%	-23.9%	

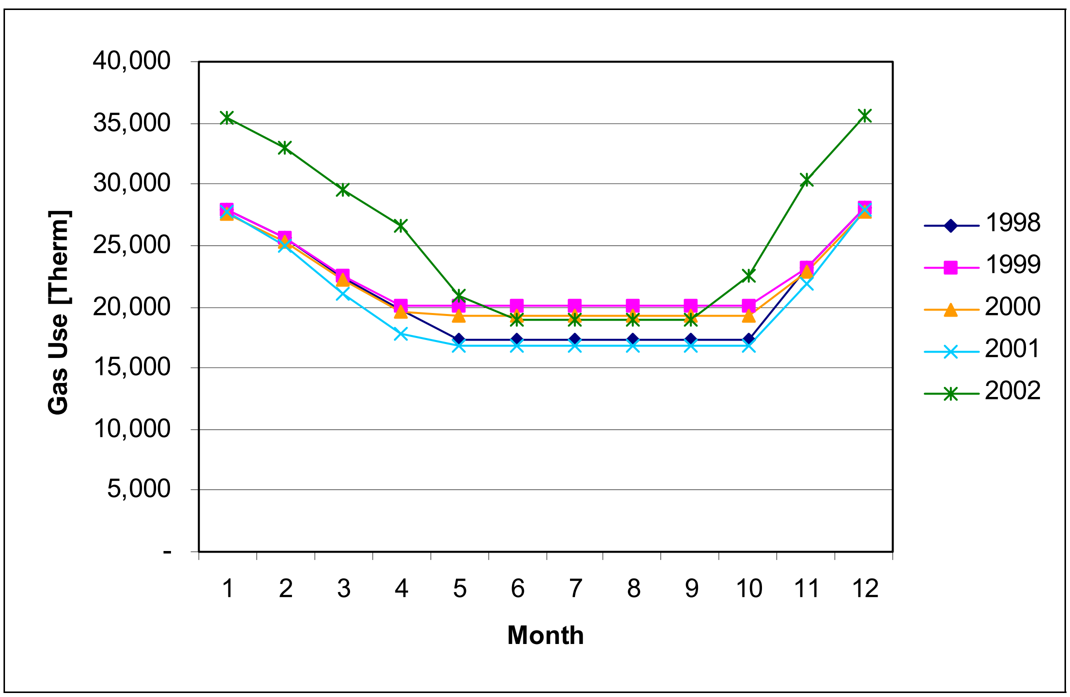

Figure 26: E-Model - Normalized Monthly Natural Gas Usage for Hospital1

Office3

This site reported poor interaction with the commissioning agent during the field work phase. The chief engineer states his view that the learning opportunity for his staff is an important benefit of retrocommissioning. He reports that learning opportunities did not materialize and there were many errors in the retrocommissioning report. The implementation record seems to bear out his assertions. Only one recommended measure has been implemented out of five recommendations. The measure called for all sensors to be calibrated and the savings benefit were immediately apparent. Another two measures were tried, but created more problems and the original settings were resumed. One of the tried-but-failed measures is significant, because it's failure can be associated with the poor retrocommissioning interactions during the field work. The recommended measure documents that the variable air volume (VAV) system was resetting the supply air temperature (SAT) at the same time as modulating the air flow. The retrocommissioning report recommended a return to true VAV operation with a fixed SAT. The staff tried the recommendation with no success. They were already sure the true problem lies with poor discharge diffuser performance at low turn down conditions, causing the supply air to drop to the floor with poor space mixing. To avoid this condition, they instituted a SAT reset routine to keep the turn down in an acceptable range. While it is unclear if this point came up in the retrocommissioning interviews, the impact this information should have on an effective recommendation is fairly obvious.

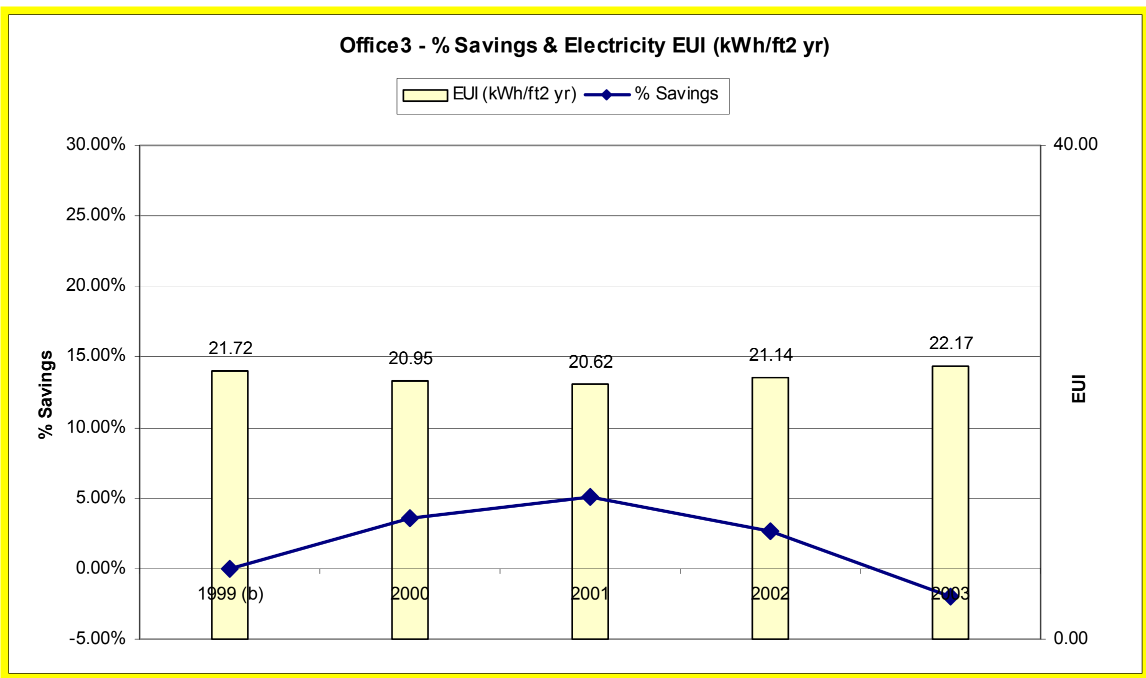

Figure 27: Electricity Savings for Office3

Table 13 and Figure 28 shows a summary of the available data for Office3.

Table 13: Actual Monthly Electricity Usage for Office3

		1999	2000	2001	2002	2003
1		645,200	595,600	705,200	613,600	654,800
2		726,800	652,800	719,200	601,600	678,400
3		648,800	612,000	708,000	636,000	688,400
4		600,800	644,000	739,200	662,800	650,800
5		675,200	697,600	731,600	744,800	819,600
6		720,800	820,400	697,600	714,400	
7		799,200	744,000	721,200	819,200	
8		807,600		666,000	754,800	
9		787,600		680,400	784,000	
10		728,400	653,600	700,800	758,800	
11		718,800	664,800	588,800	627,600	
12		698,000	707,600	549,600	691,600	
Annual		8,557,200		8,207,600	8,409,200	

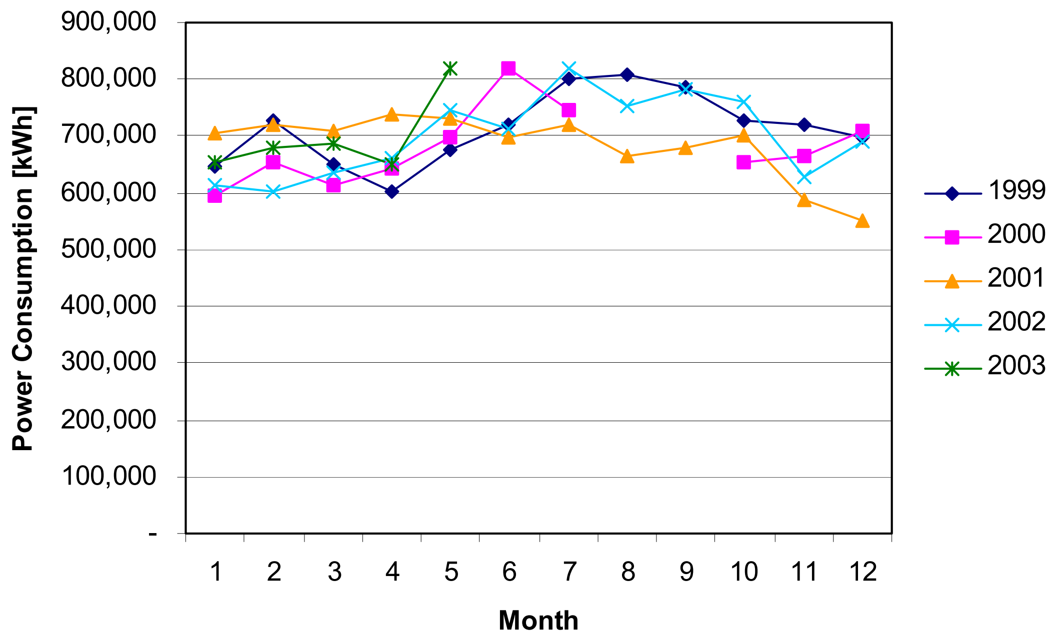

Figure 28: Actual Monthly Electricity Usage for Office3

Figure 29 shows the E-Model plot of whole building power (WBP) versus outside air temperature (OAT) for Office3.

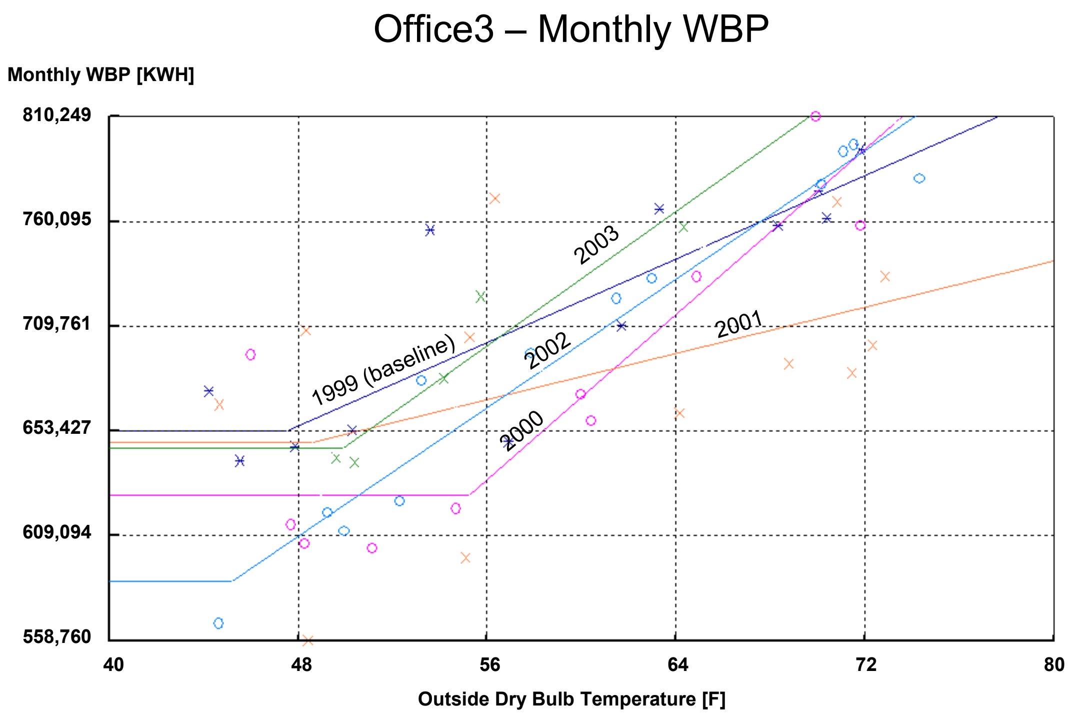

Figure 29: E-Model - kWh vs. OAT Plot for Office3

Table 14 and Figure 30 show the EModel regression model results for Office3.

Table 14: E-Model - Normalized Monthly Electricity Usage for Office3

		1999	2000	2001	2002	2003
Ycp		659675	628342	653996	587349	651097
Xcp		47.5	55.3	48.6	45.2	49.9
RS		5002	9929	2777	7718	8060
	OAT-Ave	1999	2000	2001	2002	2003
1	47.5	659,681	628,342	653,996	605,307	651,097
2	50.5	674,236	628,342	659,101	627,765	655,342
3	54.4	694,021	628,342	670,086	658,295	687,226
4	57.8	710,757	652,959	679,378	684,119	714,197
5	64.5	744,356	719,656	698,032	735,962	768,342
6	70.0	772,085	774,701	713,427	778,749	813,027
7	73.0	786,787	803,888	721,590	801,436	836,721
8	73.4	788,838	807,958	722,728	804,600	840,025
9	70.5	774,639	779,772	714,845	782,691	817,145
10	62.5	734,267	699,629	692,430	720,395	752,083
11	53.5	689,490	628,342	667,570	651,302	679,924
12	47.3	659,675	628,342	653,996	603,635	651,097
Annual		8,688,832	8,380,273	8,247,178	8,454,257	8,866,226
Saving		0	3.6%	5.1%	2.7%	-2.0%

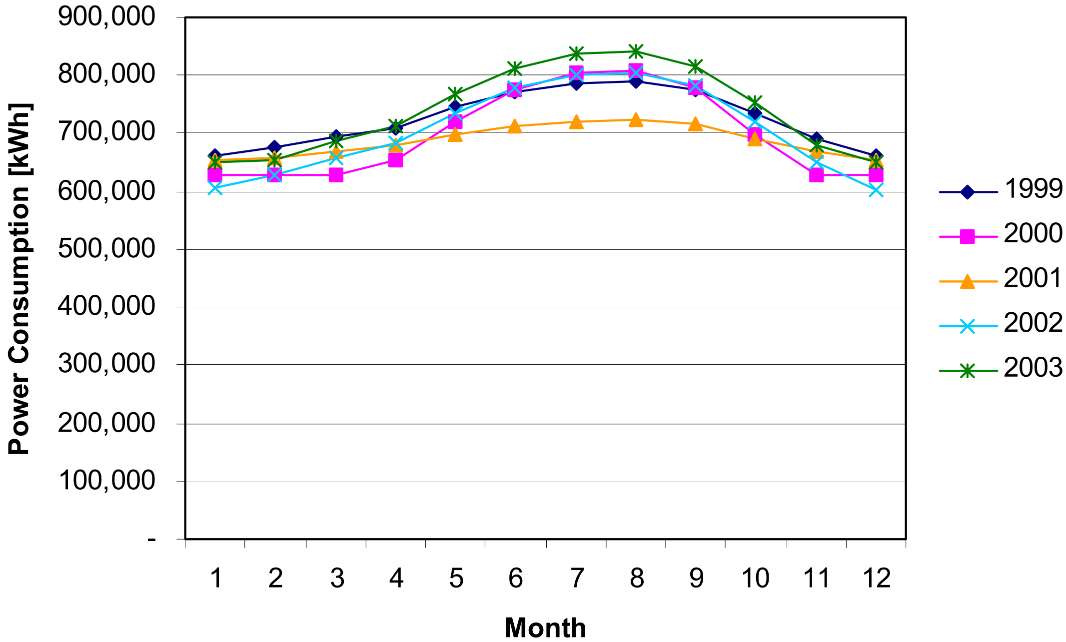

Figure 30: E-Model - Normalized Monthly Electricity Usage for Office3

Office4

The majority of the measure implementation at this site occurred in 2003. The building operations staff during the retrocommissioning field work are no longer on staff. A new chief building engineer, with previous residential HVAC commissioning experience, was hired at the beginning of 2003. He has been aggressively investigating and implementing the remaining recommendations (4 done). The energy savings analysis reconciles with the reported implementation activity, as seen in the 2003 savings (Figure 31).

A confounding factor is approximately 34,000 sf^2 of vacant tenant space during the last quarter of 2002 and most of 2003. Adjustments for this load reduction are included in the savings shown in Figure 31.

The natural gas data we obtained did not include enough 2003 data to do an estimate for that year. Whole building energy calculations for 2002 showed a 3% savings (Figure 32).

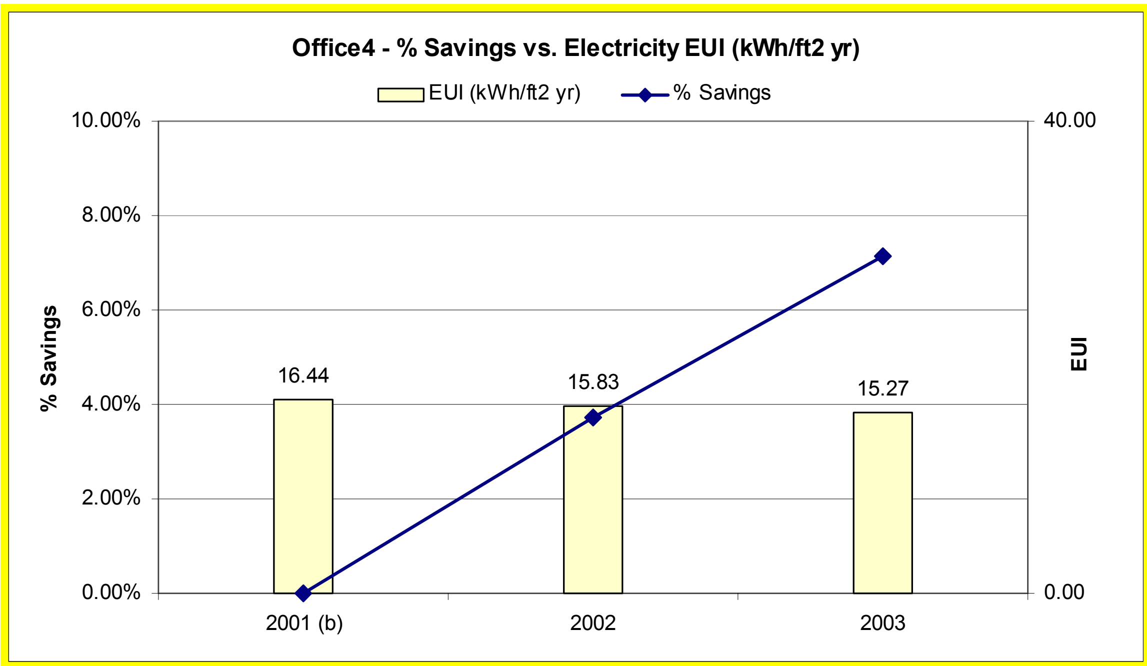

Figure 31: Electricity Savings for Office4

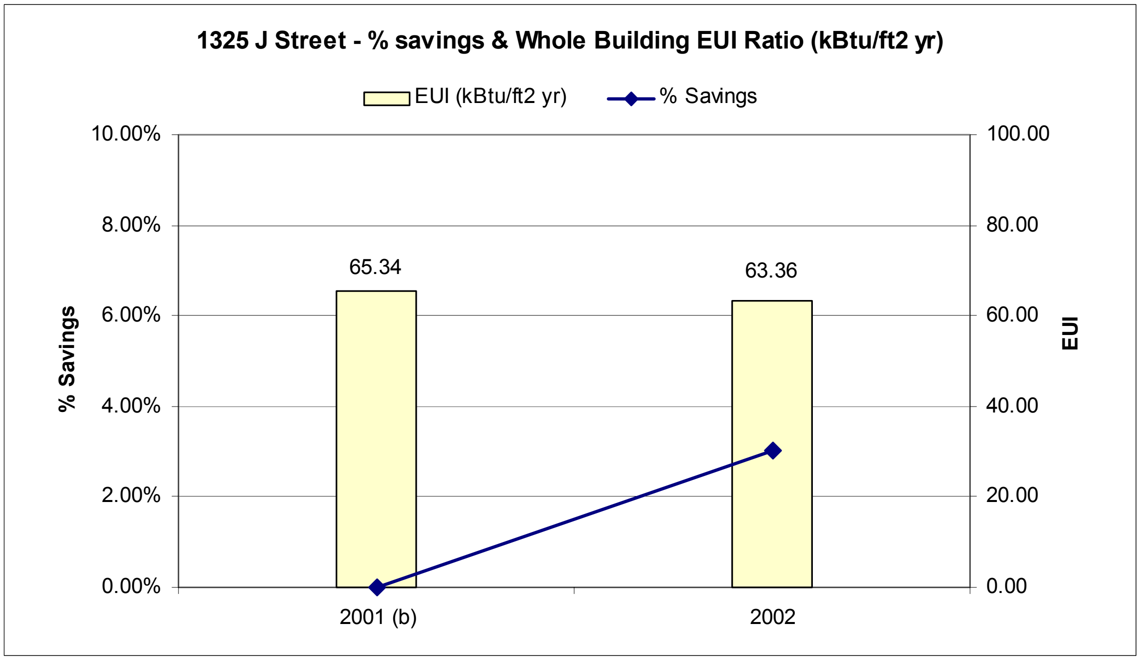

Figure 32: Whole Building (Elec. & Gas) Savings for Office4

Five of the nine recommended measures have been implemented. One recommended measure, not yet implemented, called for inspections of a faulty fan coil. The current chief engineer credits this recommendation with leading him to the discovery of a very large system calibration issue related to the diverse heating loads in the west and east air distribution zones. He predicts that the energy savings potential is very large. The repairs were underway during the last quarter of 2003.

Table 15 and Figure 33 shows a summary of the available electrical consumption data for Office4.

Table 15: Actual Monthly Electricity Usage for Office4

		1997	1998	1999	2000	2001	2002	2003
1		479,800	577,400	548,600	467,800	433,400	351,473	411,962
2		586,200	547,400	517,200	518,200	420,800	398,906	381,690
3		555,600	582,000	519,000	468,200	389,800	386,249	379,506
4		571,200	424,000	505,400	491,200	454,800	437,748	373,373
5		597,600	654,400	517,800	498,400	426,600	398,363	366,957
6		640,600	560,600	615,000	556,400	476,200	397,730	406,100
7		629,800	632,000	556,600	603,800	467,200	456,369	467,590
8		724,200	700,600	636,800	601,800	490,600	492,955	
9		667,400	712,200	589,000	571,200	475,400	435,663	
10		685,000	725,800	641,800	557,600	442,600	469,727	
11		665,600	544,000	556,400	542,800	433,000	419,191	
12		548,800	601,800	532,800	490,000	440,898	380,383	
Annual		7,351,800	7,262,200	6,736,400	6,367,400	5,351,298	5,024,757	

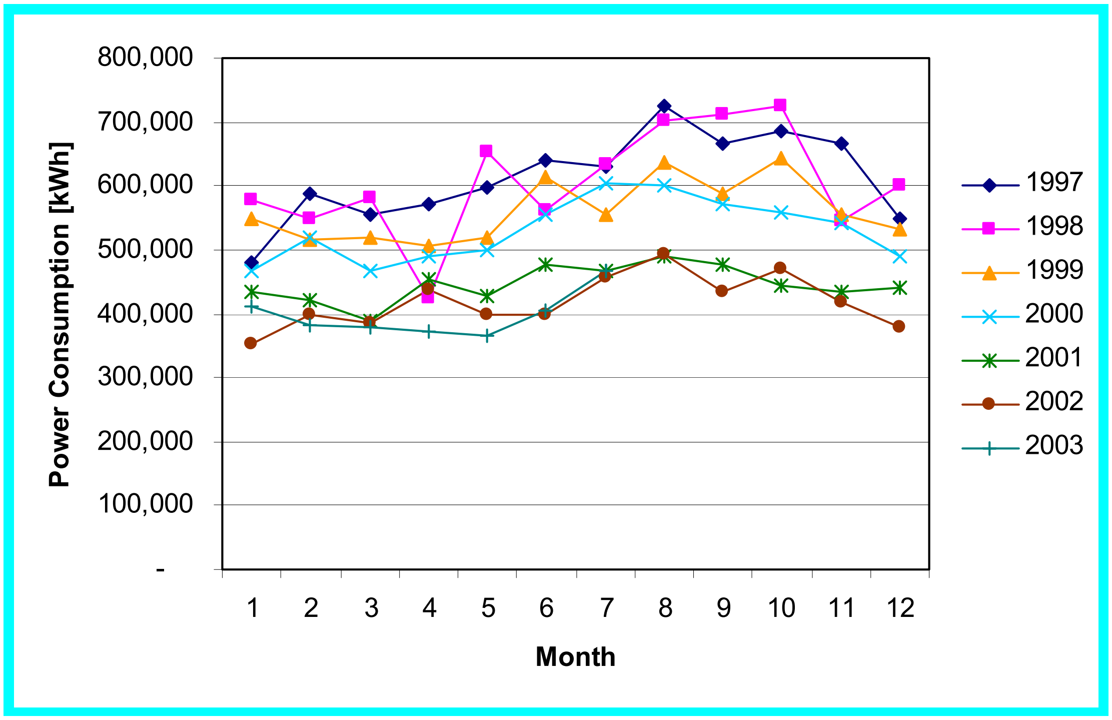

Figure 33: Actual Monthly Electricity Usage for Office4

Figure 34 shows the E-Model plot of whole building power (WBP) versus outside air temperature (OAT) and Figure 35 shows the Natural Gas versus OAT for Office4.

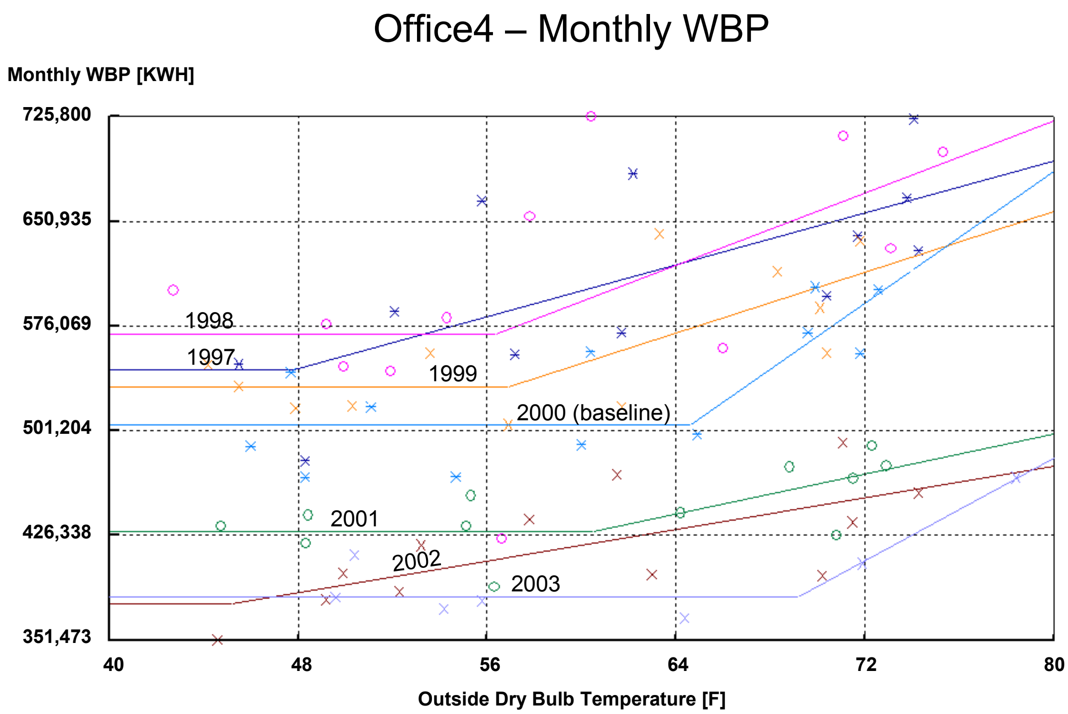

Figure 34: E-Model - kWh vs. OAT Plot for Office4

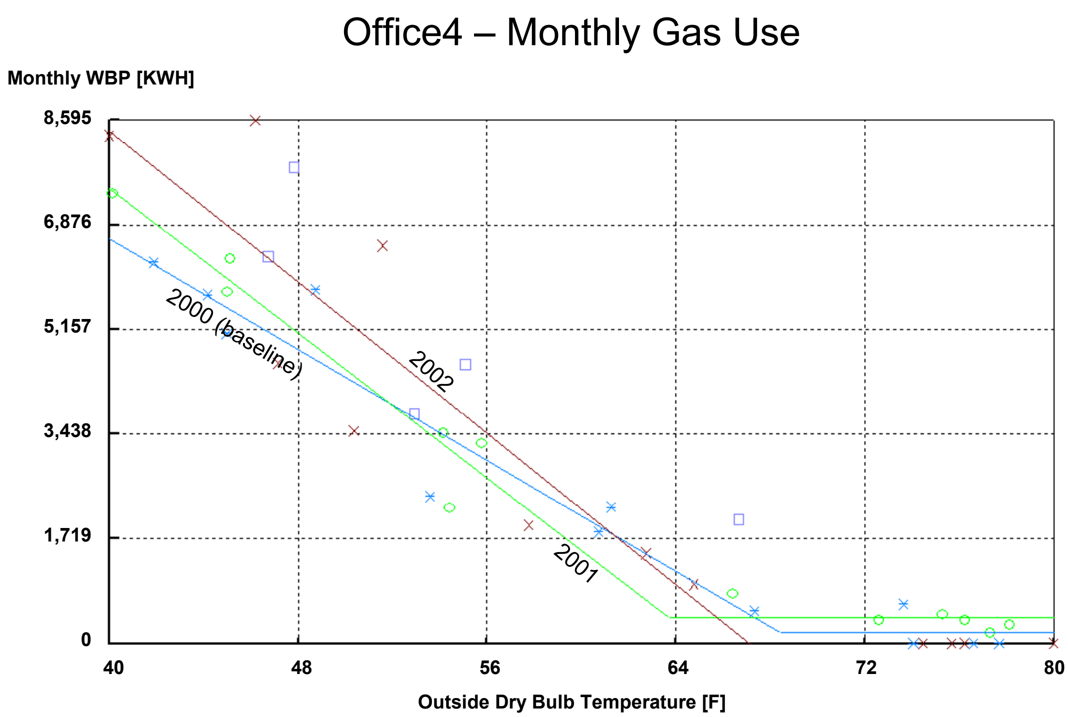

Figure 35: E-Model - Natural Gas vs. OAT for Office4

Table 16 and Figure 36 show the EModel regression model results for Office4.

Table 16: E-Model - Normalized Monthly Electricity Usage for Office4

		1997	1998	1999	2000	2001	2002	2003
Ycp		544876	569867	532161	505348	428818	377097	382505
Xcp		47.8	56.4	56.9	64.6	60.5	45.2	69.2
RS		4627	6465	5457	11799	3571	2825	9189
	OAT-Ave	1997	1998	1999	2000	2001	2002	2003
1	47.5	544,876	569,867	532,161	505,348	428,818	383,732	382,505
2	50.5	557,134	569,867	532,161	505,348	428,818	391,952	382,505
3	54.4	575,440	569,867	532,161	505,348	428,818	403,126	382,505
4	57.8	590,924	578,679	536,850	505,348	428,818	412,578	382,505
5	64.5	622,009	622,106	573,504	505,348	443,032	431,554	382,505
6	70.0	647,663	657,947	603,756	569,023	462,827	447,214	390,158
7	73.0	661,266	676,951	619,796	603,707	473,324	455,518	417,169
8	73.4	663,163	679,601	622,033	608,544	474,788	456,676	420,936
9	70.5	650,027	661,249	606,543	575,050	464,651	448,657	394,852
10	62.5	612,675	609,066	562,498	505,348	435,829	425,856	382,505
11	53.5	571,247	569,867	532,161	505,348	428,818	400,567	382,505
12	47.3	544,876	569,867	532,161	505,348	428,818	383,120	382,505
Annual		7,241,298	7,334,934	6,785,786	6,399,106	5,327,359	5,040,552	4,683,159
Saving		-13.2%	-14.6%	-6.0%	0.0%	16.7%	21.2%	26.8%

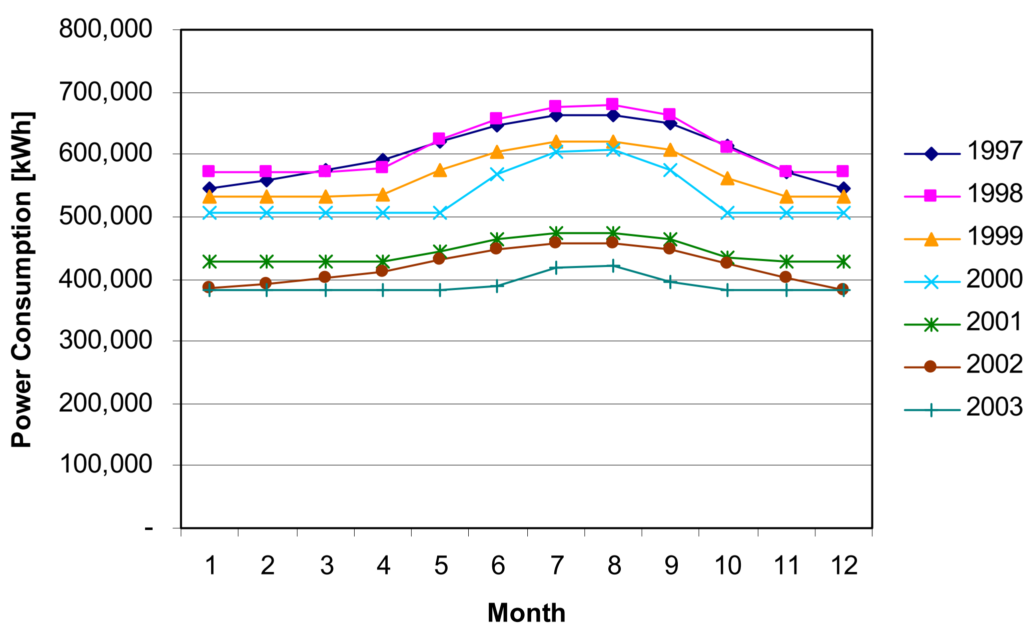

Figure 36: E-Model - Normalized Monthly Electricity Usage for Office4

Office5

All of the building operations staff during the retrocommissioning field work no longer work at this site. The average savings for this site was 4.33%. The retrocommissioning report had a total of 9 recommended measures, with 7 implemented and 2 still incomplete. One implemented recommendation is related to duct static pressure problems and has led the staff towards many other related problems and was still evolving at the time of this study.

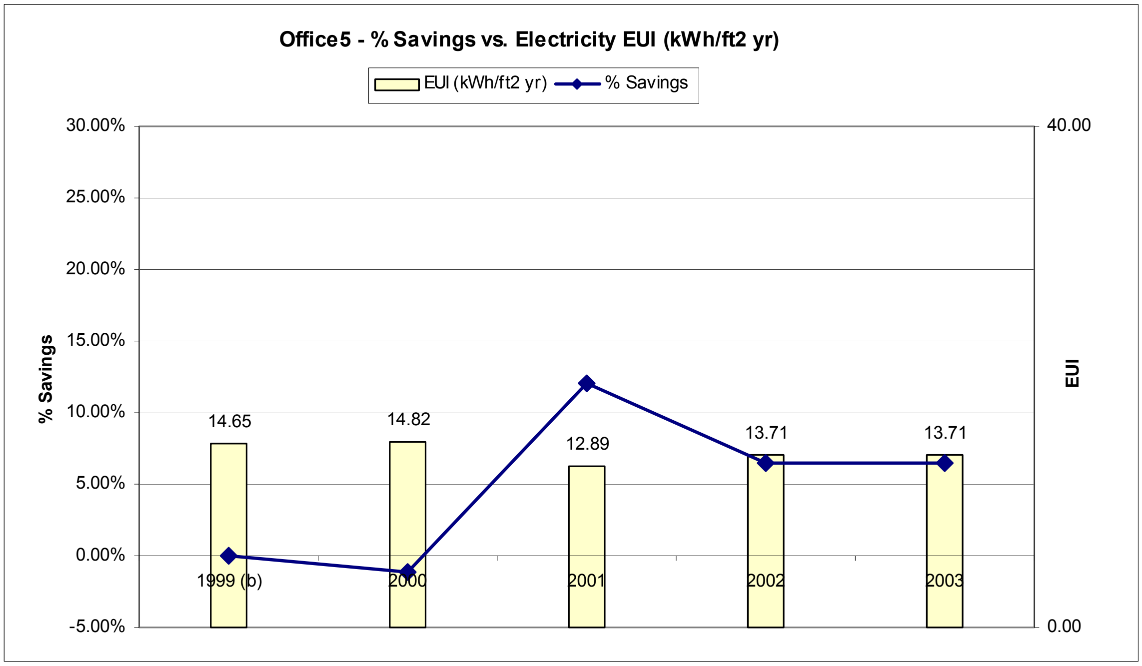

Figure 37: Electricity Savings for Office5

Table 3 and Figure 8shows a summary of the available electrical consumption data for Office5.

Table 17: Actual Monthly Electricity Usage for Office5

		1998	1999	2000	2001	2002	2003
1		402,000	382,000	440,000	350,000	370,000	380,000
2		374,000	408,000	388,000	330,000	382,000	376,000
3		382,000	398,000	404,000	356,000	362,000	356,000
4		386,000	390,000	418,000	354,000	352,000	354,000
5		380,000	402,000	460,000	424,000	400,000	408,000
6		408,000	478,000	504,000	398,000	474,000	
7		444,000	442,000	498,000	436,000	480,000	
8		484,000	464,000	456,000	418,000	416,000	
9		492,000	506,000	428,000	390,000	442,000	
10		466,000	410,000	420,000	372,000	388,000	
11		366,000	420,000	402,000	380,000	346,000	
12		404,000	394,000	356,000	328,000	396,000	
Annual		4,988,000	5,094,000	5,174,000	4,536,000	4,808,000	1,874,000

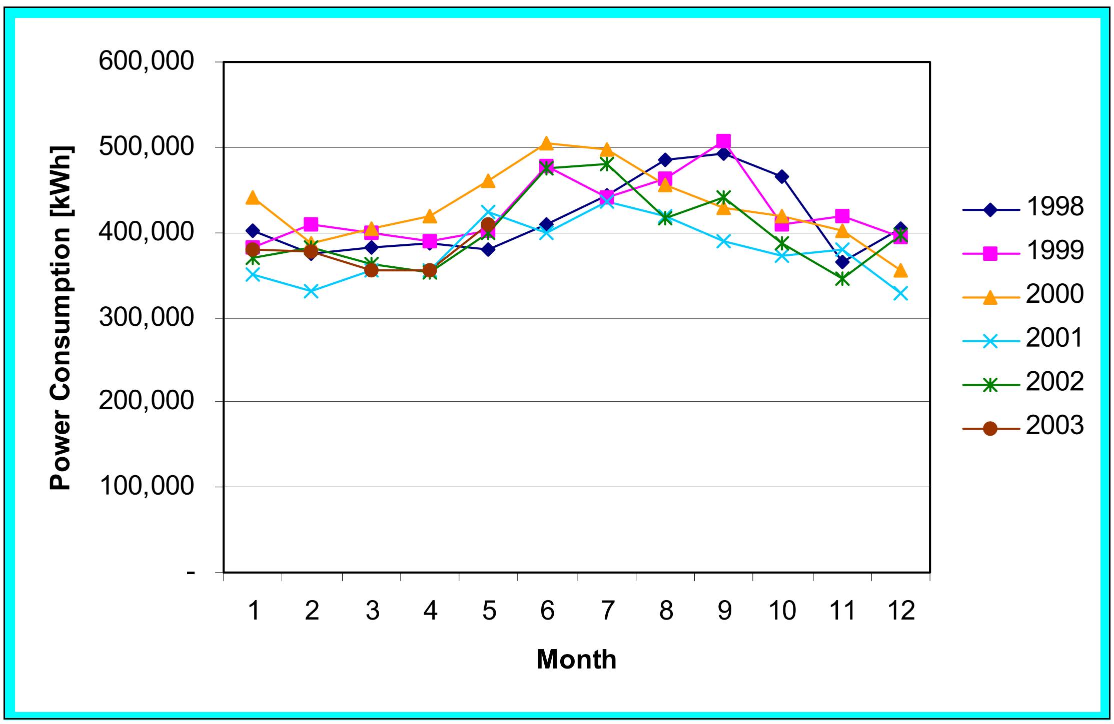

Figure 38: Actual Monthly Electricity Usage for Office5

Figure 39 shows the E-Model plot of whole building power (WBP) versus outside air temperature (OAT) for Office5.

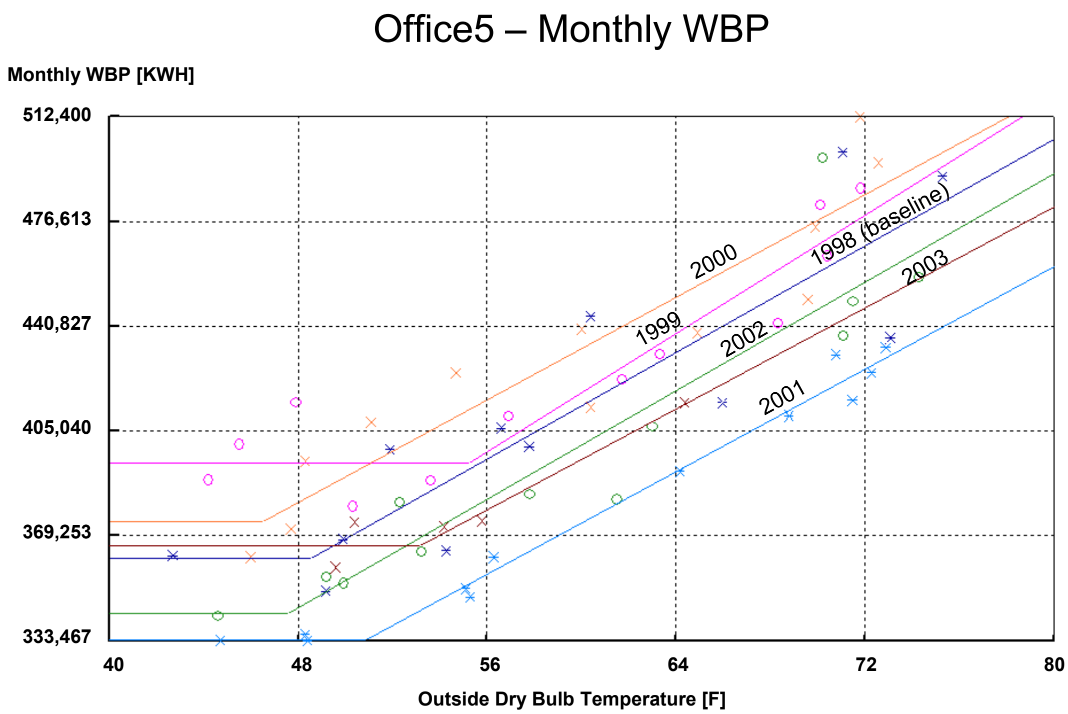

Figure 39: E-Model - kWh vs. OAT Plot for Office5

Table 18 and Figure 40 show the EModel regression model results for Office2.

Table 18: E-Model - Normalized Monthly Electricity Usage for Office 5

		1998	1999	2000	2001	2002	2003
Ycp		361693	394175	374219	333723	342518	365890
Xcp		48.6	55.2	46.5	50.9	47.6	53.2
RS		4544	5042	4372	4384	4640	4304
	OAT-Ave	1998	1999	2000	2001	2002	2003
1	47.5	361,693	394,175	378,639	333,723	342,518	365,890
2	50.5	370,259	394,175	391,360	333,723	355,896	365,890
3	54.4	388,233	394,175	408,653	349,090	374,252	371,300
4	57.8	403,437	406,856	423,281	363,761	389,779	385,702
5	64.5	433,960	440,724	452,647	393,214	420,949	414,615
6	70.0	459,151	468,675	476,883	417,521	446,675	438,476
7	73.0	472,508	483,495	489,734	430,409	460,315	451,128
8	73.4	474,371	485,562	491,526	432,206	462,217	452,893
9	70.5	461,472	471,250	479,116	419,760	449,045	440,675
10	62.5	424,795	430,554	443,829	384,370	411,590	405,933
11	53.5	384,116	394,175	404,692	345,118	370,048	367,401
12	47.3	361,693	394,175	377,692	333,723	342,518	365,890
Annual		4,995,690	5,157,994	5,218,052	4536618.912	4825799.98	4825793.4
Saving		0	-3.2%	-4.5%	9.2%	3.4%	3.4%

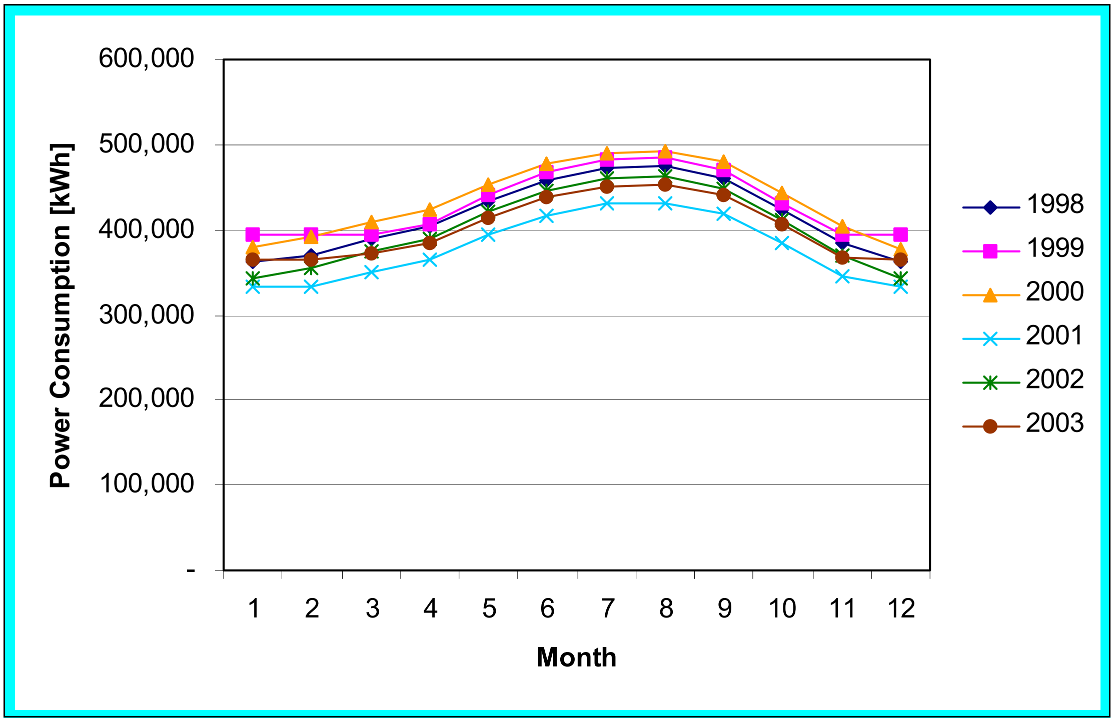

Figure 40: E-Model - Normalized Monthly Electricity Usage for Office 5

Office6

There has been a high implementation rate at this site. Energy savings have averaged approximately 12.55% per year. The retrocommissioning report recommended 10 measures and the site staff have implemented 8. At least three of the BAS related recommendations only started to address their associated condition and the BAS adjustments are continuing to evolve under a service contract the site has with a BAS commissioning contractor.

This site was under a major building renovation in 2003. This site has recently acquired internal funding for a new complete retrocommissioning study of the facility.

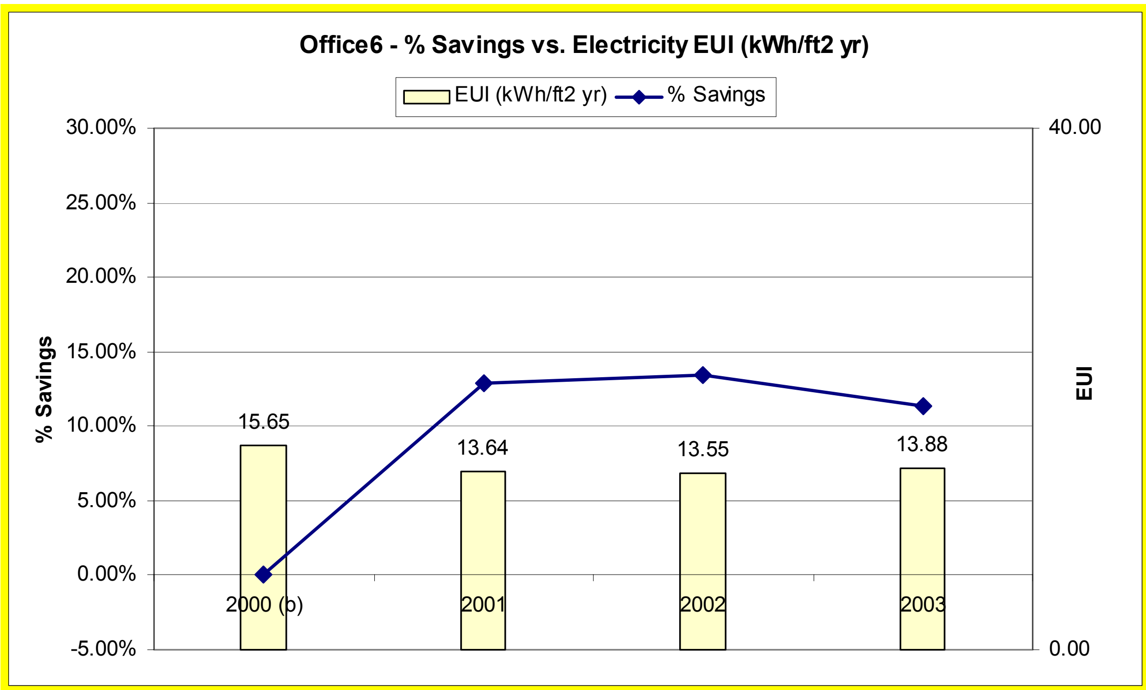

Figure 41: Electricity Savings for Office6

Table 19 and Figure 42 shows a summary of the available electrical consumption data for Office6.

Table 19: Actual Monthly Electricity Usage for Office6

		2000	2001	2002	2003
1			305,481	311,756	327,980
2			307,770	308,993	312,823
3			317,740	290,510	316,817
4			318,786	338,019	328,058
5			368,358	343,989	383,782
6			393,435	366,959	368,155
7			434,281	411,082	460,103
8			422,481	397,724	410,577
9			392,799	392,571	
10		395,407	338,865	339,823	
11		366,503	332,098	333,237	
12		324,223	282,156	302,049	
Annual			4,214,250	4,136,712	

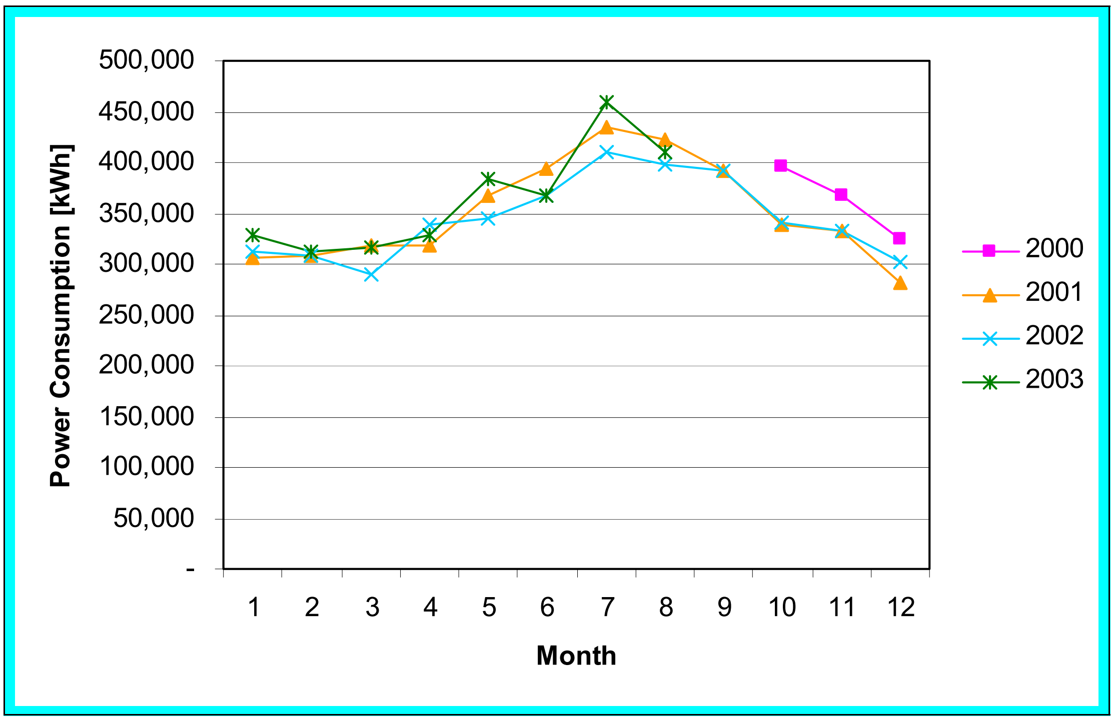

Figure 42: Actual Monthly Electricity Usage for Office6

Figure 43 shows the E-Model plot of whole building power (WBP) versus outside air temperature (OAT) and Figure 44 shows the Natural Gas versus OAT for Office2.

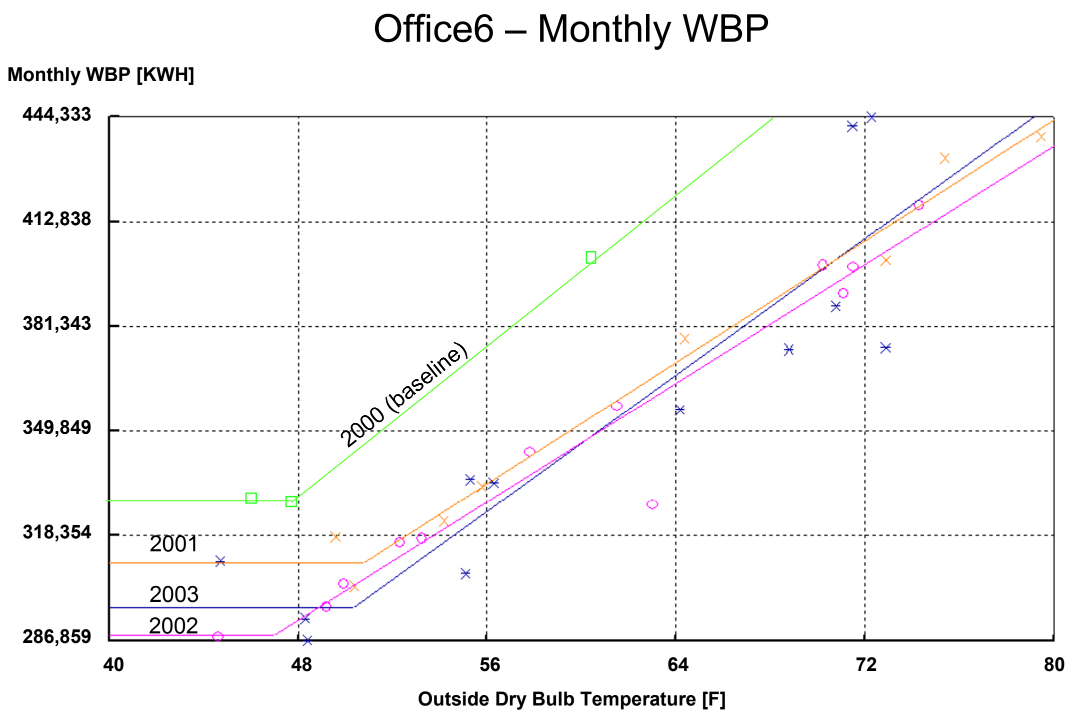

Figure 43: E-Model - kWh vs. OAT Plot for Office6

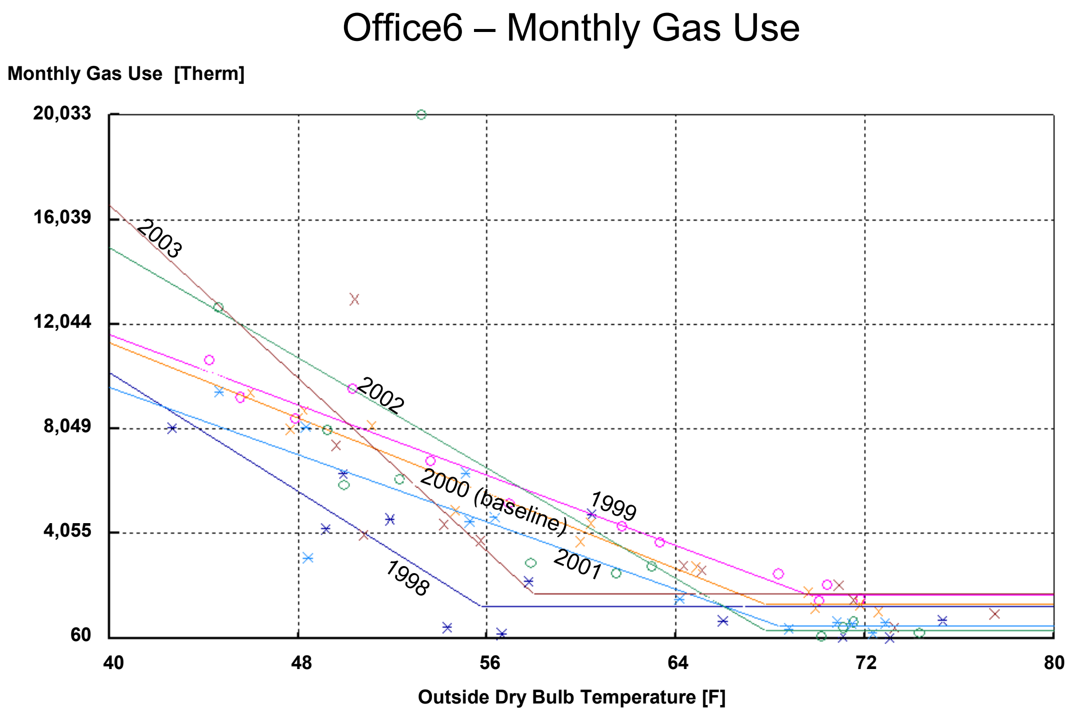

Figure 44: E-Model - Natural Gas vs. OAT for Office6

Table 20 and Figure 45 show the EModel regression model results for Office2.

Table 20: E-Model - Normalized Monthly Electricity Usage for Office6

		2000	2001	2002	2003
Ycp		329201	296596	288323	310248
Xcp		47.7	50.3	47.0	50.8
RS		5745	5122	4454	4559
	OAT-Ave	2000	2001	2002	2003
1	47.5	329,201	296,596	290,850	310,248
2	50.5	344,856	297,175	303,812	310,248
3	54.4	367,581	317,437	321,432	326,718
4	57.8	386,804	334,575	336,337	341,973
5	64.5	425,394	368,982	366,260	372,596
6	70.0	457,242	397,378	390,955	397,870
7	73.0	474,129	412,435	404,049	411,271
8	73.4	476,484	414,534	405,875	413,139
9	70.5	460,176	399,994	393,230	400,198
10	62.5	413,806	358,651	357,275	363,401
11	53.5	362,376	312,796	317,397	322,588
12	47.3	329,201	296,596	289,885	310,248
Annual		4,827,250	4,207,149	4,177,355	4,280,497
Saving			12.8%	13.5%	11.3%

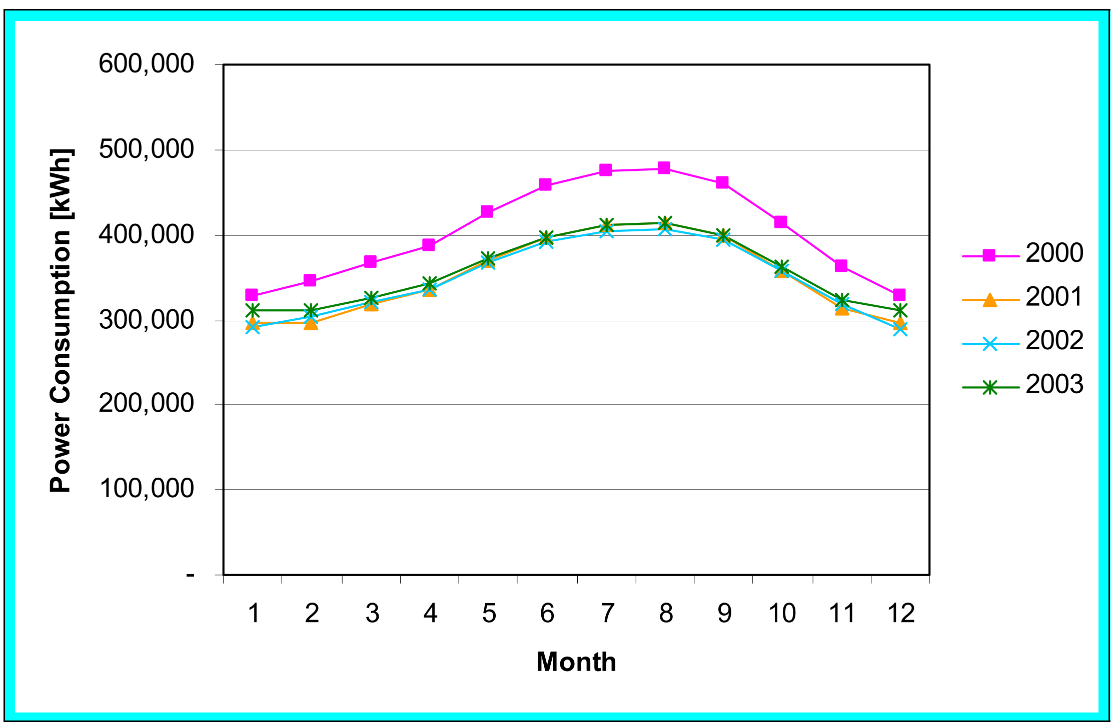

Figure 45: E-Model - Normalized Monthly Electricity Usage for Office6

EVALUATION OF PERSISTENCE OF SAVINGS FROM SMUD RETROCOMMISSIONING PROGRAM FINAL REPORT

INTERVIEW NOTES - RAW DATA

APPENDIX C

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Office1

Interview Notes:
Date: Aug. 20, 2003.

Attend: Building Engineer, Building Manager,
Mazen Kellow & Richard Green – SMUD, Naoya Motegi & Norman Bourassa – LBNL

Interview Questions

1. Is there energy billing data for the computer data center in Building No. 1? If not, what information can we use to develop an estimate?
   No separate energy usage meter. We can meter at the generator transfer switch for all data center consumption. Readings from UPS' will indicate server usage Transfer minus UPS equals chillers and air handlers

2. How did you become aware of the BAS Recommissioning program?
   Through Mazen Kellow at SMUD.

3. Do you have any estimates of yearly energy savings due to BAS Recommissioning program? No

4. Who pays the energy costs for Building No. 1? owner

5. Do you consent to publishing an entry to the *CCC Case Study Protocol 1.0 Existing Building Commissioning* Database? Unsure at this time

Additional notes:

Building Engineer: In truth, he thinks they didn't respond as rigorously to the BAS Report as they could have. In fact this has been the first time they looked at it again.
They are in the process of setting up a "Maintenance Manager" software.
Currently, they do not have any type of maintenance logs, including hand written hard copies.
He said their largest problem at the moment is the lack of a good in-house maintenance planning procedure program.

Implementation Costs:

~$2000 total for all the programming measures.
Additional coast of ~$3000 for supporting trends and other data (? NJB – They were not clear on this cost)

Additional Questions (12/15/03 & 12/22/03):

For Building Engineer (Green answers given in 12/22/03 email; Red answers provided in 12/15/03 telephone conversation)

Measure implementation:

Was the Chilled Water Reset (CH-1,2,3,4), measure #1, implemented?
Vendor felt that chillers more efficient at higher load and varying fan speed was more economical CH1-2
Need to maintain lower water temperature (44) for dehumidification CH3,4,5

Was the Modify S/S criteria per ambient conditions & call for cooling (CH1,2), , implemented?
Done

Was the Condenser water reset measure implemented?
No
Have you determined whether the Hot Water Supply Reset (B-1) can be programmed?
The systems can't be programmed for this.

Have you determined if the Modify PI parameters to prevent "hunting" valves (SF-3 heating, AH-1 cooling) measure has been implemented? Recall that SMUD records show it was, but you thought it was not.
Cannot verify

General Cx questions:

Describe positive impacts of commissioning.
Keeps energy conservation/efficiency topic on our agenda. Good overview of the working conditions of the system
Describe negative impacts of commissioning.
None

How do you justify commissioning costs?
Energy and equipment savings

What are some lessons learned from this project?
Follow through and follow up is important

Would you commission another building in the future? Why or why not?
Yes, if time and resources allow

Do you expect to re-commission your building again? If so, what will trigger re-commissioning?
No, this project covered all areas and should remain effective for some period

Have any measures been modified since their original implementation?
No (per telephone conversation with Curtis, 12/15/03)

Office2

Interview Notes:
Date: Sep 19, 2003.

Attend: Building Engineer,
Richard Green – SMUD, Naoya Motegi & Norman Bourassa – LBNL

Interview Questions

1. Please identify which of the following activities worked well with your commissioning project?

   a. Issues identified and resolved in a timely manner
      Yes
   b. Good communication among cx team members
      Yes
   c. Quality of training received by the building staff
      Yes
   d. Other: _________________

   ESS executed perfectly, "It was a pleasure." Other than some errors in the first draft of the report, there were no problems.

2. Describe positive impacts of commissioning.
Energy consumption has gone down and equipment life is extended. Also noticed that Hot & cold calls have likely gone done too.

3. Describe negative impacts of commissioning.
Information is not always correct and accurate – e.g. prelim report. Also, it's a large time investment for the operator crew (but he adds that it is "a price well paid.")

4. How do you justify commissioning costs?
We absorb it under Repairs & Maintenance (R&M). Estimate our total implementation cost at ~ 5 man days.

5. What are some lessons learned from this project?
"It pays to invest the time for a third party to evaluate your building. Owners and managers will fund projects that have been reviewed or recommended by a P.E."

6. Would you commission another building in the future? Why or why not?
"Yes, same as above.

7. Do you expect to re-commission your building again? If so, what will trigger re-commissioning?
"Yes, I would like to evaluate the hot water system and other smaller areas of concern."

8. Do you have plans in place that will improve the persistence of commissioning benefits over time? If so, please describe.

"We have goals outlined in a Utility Management Plan."

9. How did you become aware of the SMUD BAS Recommissioning program?
" Sandy Butts, from SMUD.

10. Do you have any estimates of yearly energy savings due to BAS Recommissioning program?
"I have a comfort level with the job we do, but I can't attach a dollar amount."

11. Do the tenants pay their utility bills directly?
"No. Poperty Management company pays the bill."

12. Do you consent to publishing an entry to the *CCC Case Study Protocol 1.0 Existing Building Commissioning* Database? If so, please have an authorized company official sign the Release Statement.
"Prior authorization will need to be Obtained."

Additional notes:
Building Engineer:
Chiller plant has EnerLink sub meter, 15 minute interval.

- It's easier for SMUD to retrieve the data
- Jim G will contact Fred Webb (at SMUD) and get the before and after chiller retrofit data.

For one year (2002), they did a per floor sub-meter monitoring of the high-voltage electrical panels (floor 2 to 17).

- Lighting
- Plug loads
- Mechanical risers

Richard will work with Fred to get this data for us.

Note:
~ 6 months ago, they did a pilot test for the Whole Building Diagnostician. The Building Engineer has a small test result report he will share with us (we received by fax on 9/29/03). He said he wasn't impressed by the WBD and didn't think it was a good fit for their facility.

Outstanding Questions (1/7/03):

For Building Engineer – Answers given during telecon 1/7/03

What is the estimate of time/cost to the building operations staff to accommodate/escort the Cx Agents? You state ~5-7 man days … this = $?
~$1500

Have you determined if the "Repair VSD" measure was implemented. If yes, what are the details and the cost?

AH1 – We decided the SAT is high enough that the boxes mostly run full out and VAV operation is not occurring. This is a standard operating condition that will require major renovations to repair. Design condition.
AH6 – Operator error. Someone had put into manual mode.
Zero cost, it was not done.

Were the lighting EMS controls extended through all the floors or just seven floors during 2002? Please confirm the cost. I have ~$15,000 as the amount.

No we are done all except for 18. Lobby thru 17 done, as of 1st quarter 2003. No plans, to do 18. Done I groups at approx. 3000 per group. Controls only, because building was already rough.

Have any measures been modified since their original implementation? No If so, what is the new setting? Why was it changed?

Lab1

Interview Notes:
Date: Sep 23, 2003.

Attend: Energy Manager,
Mazen Kellow – SMUD, Naoya Motegi & Norman Bourassa – LBNL

Interview Questions

1. Please identify which of the following activities worked well with your commissioning project?

   a. Issues identified and resolved in a timely manner
   Energy Manager – Yes, almost no investment on this. Too small to account for (refer to NCB 2003 paper)
   b. Good communication among cx team members
   Energy Manager – Yes, the building operator staff picked up a lot of ideas from the Cx team. Jerry was given an award for his work on this project.
   c. Quality of training received by the building staff
   Same as b.
   d. Other: ________________

2. Describe positive impacts of commissioning.

Energy Manager – Training aspects described above. Customer satisfaction was not compromised by the Cx process

3. Describe negative impacts of commissioning.

Energy Manager – The distraction from normal operations. However, this minimal price may be worth it for all the benefits.

4. How do you justify commissioning costs?

Energy Manager – For a $25k study, the savings were ~$125k. Very easy to justify.

5. What are some lessons learned from this project?

Energy Manager – We have learned that Cx of a new building is necessary and it should be the responsibility of the owners/operators. The county is planning to implement a policy for new construction Cx, funded by the budget of the land owner/department and administered by the county energy office.

6. Would you commission another building in the future? Why or why not?

Energy Manager – Yes. He would like to RetroCx more buildings, but he doesn't know exactly how to proceed.

7. Do you expect to re-commission your building again? If so, what will trigger re-commissioning?

Energy Manager – Yes. How to determine when, he doesn't know exactly. Maybe a prompt from the EEM tool he uses. He feels an interval of ~4 to 5 years for RetroCx.

8. Do you have plans in place that will improve the persistence of commissioning benefits over time? If so, please describe.
   Energy Manager – Plan to implement a rigorous work order system within their Computer Assisted Facility Management (CAFM) system, to trigger re-evaluations. Creating a formal protocol for this.

9. How did you become aware of the SMUD BAS Recommissioning program?
   Energy Manager – From Mazen Kellow.

10. Do you have any estimates of yearly energy savings due to BAS Recommissioning program?
    Energy Manager – ~$125k to $130k per year. (See the NCBC 2003 paper). And he says they are seeing it!

Do you consent to publishing an entry to the *CCC Case Study Protocol 1.0 Existing Building Commissioning* Database? If so, please have an authorized company official sign the Release Statement.
Yes.

Additional notes:
Energy Manager:
Problems with the Chiller:

- They are running an excessive number of hours at very low part load, ~ 35%. As a result they are cutting out a lot, with the associate wear issues.
- They are planning to put in a pony chiller to handle these hours.

He is in the process of analyzing chiller sub-meter data to calculate:

- Chiller efficiency
- Part load hours
- Pony chiller sizing

Currently, he is pulling the BAS data into the Silicon Energy EEM tool, for analysis.

Only available interval data point is Whole building.

Energy Manager says a large factor in his building operation is a "quarterly memo I send out to have the thermostats set to comfort levels and set backs for the current season." The adjustments are manuals, prompted by the reminder memo. There are no plans to automate this.

Other notes:

- Additional measures beyond the RetroCx recommendations were developed by the operators and they implemented them. These measure would not have been implemented if not for the RetroCx effort! Energy Manager offer to have the HVAC Technician put together a list of these measures.

- He only has an operator on-site ~2 day per week.
- He expects the savings to flatten at about 14 to 15%. It started at 20%.
- Avoided Costs: He says this is more of a factor of the day-to-day operation of the building. If the cost has been budgeted, then reduced savings are obtained. If it has not been budgeted, then avoided costs are created.

Outstanding Questions (1/20/04 & 1/27/04):
For Energy Manager. Provided 1/20/04 & 1/27/04

What is the estimate of time/cost to the building operations staff to accommodate/escort the Cx Agents?

~ 20 or more hours. At that time, the billing rate it was ~ $50/hr. Rate now is $75.

What are the details on the By-pass timers for AHU-1&2 and AHU-5? The NCBC Paper does not have any details on the implementation. Implementation cost?

It is difficult to determine the actual implementation cost, because only the work ticket is in the records. All the other man hours (such as Energy Manager's time) is not included. The Cx Agent estimate (the ones included in the NCBC Paper) are high. For example the work ticket for AHU 5 timers was approximately $500, adding in other costs such as electrician and his time will raise it, but not too 1875

Have any measures been modified since their original implementation? If so, what is the new setting? Why was it changed?

No. Al Curtis is the original engineer for the CC&C, when it first started up. I will confirm this with the current engineer.

1/27/04: Energy Manager has confirmed status of all the measures. NOTE: He is un sure about whether the Reprogram lighting sweep controls measure has been done. He will check again and get to me.

.
What did your facility do during the 2001 energy/demand crisis?
Sent out a memo to all facilities to setup/setback Tstats by 2 deg F. He doesn't know the level of implementation at CC&C Lab.

Hospital1

Interview Notes:
Date: Oct. 1, 2003.

Attend: Chief Engineer,
Richard Green – SMUD, Naoya Motegi & Norman Bourassa – LBNL

Interview Questions

1. Please identify which of the following activities worked well with your commissioning project?

    a. Issues identified and resolved in a timely manner
    Yes
    b. Good communication among Cx team members
    Yes
    c. Quality of training received by the building staff
    Very good
    d. Other: ________________
    Synergy between Cx Team and the interested staff members, helps to validate extra effort for facilities staff.

2. Describe positive impacts of commissioning.
Chief Engineer – Helps to validate our suspicions of energy waste. Helps to focus our efforts. Helps the staff improve their self image and confidence.

3. Describe negative impacts of commissioning.

Chief Engineer – It takes extra time and effort.

4. How do you justify commissioning costs?

Chief Engineer – It is the right thing to do for the environment, the economy and the building operation budget.

5. What are some lessons learned from this project?

Chief Engineer – Not to ignore ANY source of energy consumption.

6. Would you commission another building in the future? Why or why not?

Chief Engineer – Of course. Reasons: verification of proper equipment performance, instead of energy savings, is our number one driver.

7. Do you expect to re-commission your building again? If so, what will trigger re-commissioning?

Chief Engineer – Yes. Although, grant money or utility subsidies are needed because of a lack of internal budget availability.

8. Do you have plans in place that will improve the persistence of commissioning benefits over time? If so, please describe.

   Chief Engineer – Internal energy group, energy staff with regular meetings. Plan to put in new monitoring equipment.

9. How did you become aware of the SMUD BAS Recommissioning program?
   SMUD Account representative.

10. Do you have any estimates of yearly energy savings due to BAS Recommissioning program?
    Chief Engineer – Yes, we made estimates. See the NCBC 2003 paper.

Do you consent to publishing an entry to the *CCC Case Study Protocol 1.0 Existing Building Commissioning* Database? If so, please have an authorized company official sign the Release Statement.
Chief Engineer – Yes.

Additional Notes:
Chief Engineer: The fans in the facility were run/designed with really high static, ~ 10"! He reduced it and they are now running ~6", although this is still quite high.

Other big issues:

- Lowered steam pressure from 100 psi to 60
- Lowered heating water from 180 deg F to 140
- Took one heat exchanger (steam to hot water) -> now running entire building on one -> significant effect on N Gas consumption is apparent. This was done at the end of Mar, 2003. He did this because of the high forecast prices for N Gas this winter.
- The largest constraint in measure implementation he has is the lack of monitoring data. He wants to expand the Enerlink data to help in this area.

Capital Intensive Measure that were at very back of the PECI report (but not in the site interview document table):

B-01 & B-03
Actually did a new duct transition -. It helped, but they still need to do more. Studies are under way. Basically, the air intake duct is way too long, producing too much static.

G-04
Not done. Studying how to do this without any condensate accumulation in the ducts.

Outstanding Questions (1/9/04):

for Chief Engineer Answers given during telecon 1/9/04.

What is the estimate of time/cost to the building operations staff to accommodate/escort the Cx Agents? 40 to 60 hrs at ~$55/hr

Are any of the fluid loops variable flow? Yes, all are except the CW flow through the chillers.

How much time/cost do estimate your staff expended for the measure implementation? (the * items in the NCBC paper) BAS programming and modification done by the O&M Staff. ~240 hrs for all the BAS and mods.

I need to confirm the status of these recommended measure:

- E-02 Chilled water supply temperature setpoint is fixed at 44 F
  - Not implemented as recommended. Modified implementation: Resetting CCWT based on AHU CCW valve positions (14 AHUs), temperature modulates from 56 F to 44 F, at ~2F per 10% of valve position. The most open valve in the loop determines the temperature. E.g. If at least one AHU is at 90% then CCWT is ~47 F, if one is 100% then CCWT is 44 F.
- F-01 Make the condenser water as cold as possible, but above the minimum limit of chiller. Two cell cooling tower, that can run two chillers. Driving CW to 78F.
  - What is min temp chillers can handle? Somewhere in the 60s
  - How was this implemented? Adjusted the controller.
- H-01 Room 537: Did this:1)Labels to encourage only one band of lights ON during day, ~~2) de-lamp qty of 2 from each fixture~~
- H-02 Install occupancy sensors in board room Didn't do. Educated the staff. They have been pretty good on the lights, but less good on turning of the AHU10 serving the room.
- H-03 Operating Room Lights: 1) Consider installing a lighting sweep for areas that don't need lighting at night, OR 2) Did this: Implement a policy so that the occupants of the area or security staff turn out the lights at the end of the typical day (6pm or so).
- H-04 Repair the exterior lighting time clock Yes, did that. Cost ~ $160

Have any measures been modified since their original implementation? Yes

If so, what is the new setting? Why was it changed? NJB – see ImplementationTally.xls work book for details on the changes to A-01.

What did your facility do during the 2001 energy/demand crisis?
Yes they did do hallway lights (50% of the lights) for approx 2/3 of the hours. Still doing today. Also did some de-lamping.
Also reduced steam pressure from 100psi to 65psi – this provided natural gas savings.

Office3

Interview Notes:

Date: Oct. 1, 2003.

Attend: Chief Engineer,
Richard Green – SMUD, Naoya Motegi & Norman Bourassa – LBNL

Interview Questions

1. Please identify which of the following activities worked well with your commissioning project?

   a. Issues identified and resolved in a timely manner
      Yes, but only one measure was fully implemented. They other measures didn't work
   b. Good communication among cx team members
      Building engineers had almost no interaction with the Cx Team.
   c. Quality of training received by the building staff
      None received.
   d. Other: _________________

2. Describe positive impacts of commissioning.

Chief Engineer – It got us thinking about controls and building operations. But we didn't go far enough with the process.

3. Describe negative impacts of commissioning.

Chief Engineer didn't see many negative impacts.

4. How do you justify the commissioning costs?

Chief Engineer – N/A, because we didn't have any significant implementation costs.

5. What are some lessons learned from this project?

Chief Engineer – 1) You have to pay more attention to the building or it operations will deteriorate. 2) It would be good to identify one person on the building operations staff to be responsible for the energy manager tasks.

6. Would you commission another building in the future? Why or why not?

Chief Engineer – Yes, absolutely.

7. Do you expect to re-commission your building again? If so, what will trigger re-commissioning?

Chief Engineer – Yes, in anew years. We could go astray very easily. However, we will need some sort of external funding, because we do not have internal budget for Cx.

8. Do you have plans in place that will improve the persistence of commissioning benefits over time? If so, please describe.
   Chief Engineer – Yes, in one aspect. Hot and cold calls are done with the Test & Balance report in hand and engineers are not allowed to change any settings without my approval. This way settings don't get altered in an uncontrolled/supervised manner.

9. How did you become aware of the SMUD BAS Recommissioning program?
   SMUD Account Representative.

10. Do you have any estimates of yearly energy savings due to BAS Recommissioning program?
    Chief Engineer doesn't know if there are any. Only the sensor calibration was done.

11. Do the tenants pay their utility bills directly?
    Chief Engineer – Building management pays and passes through costs to the tenants.

Do you consent to publishing an entry to the *CCC Case Study Protocol 1.0 Existing Building Commissioning* Database? If so, please have an authorized company official sign the Release Statement.

Chief Engineer – Likely, but not my decision. I can deliver the finished version to the building manager.

Additional Notes:

Chief Engineer:

He has been trying to management to conduct a T-8 retrofit for the last several years. The Owners have now scheduled it for 2006.

BAS – New system is scheduled for installation in 2006 as well.

One thing ESS missed:

- 110,000 kWh/month for a computer data center tenant (current energy use). In Nov of 2000, they averaging ~80,000 kWh/month.
- This is ~ 1/3 of the total building electricity bill
- ESS was informed of the center, but they didn't identify any measures for the data center
- Chief Engineer was disappointed that there was no discussion of the computer center in the report.

In fact, Chief Engineer was generally disappointed with the Cx report

EnerLink Channel available:

Panels 1 & 2 and the Chillers.

Chief Engineer:

The Cx exercise got them thinking about the Lobby and ground level, which had 4 air handlers serving it. They shut down 2, with no occupant complaints, so they shut down another and now only one AHU runs for the post office on the first floor. This was done during first quarter of 2002.

Outstanding Question (1/7/04):

Chief Engineer - Answers given during telecon 1/7/04

Cx Agent field work accommodations at ~ 8hrs of operators time at $50/hr rate.

How much time/cost do estimate your staff expended for the measure implementation?
3hrs time at ~$50/hr. JCI time was included in contract. (Sensor calibration)

Have any other measures been done since we talked?
Yes. Chief Engineer found some money to do the 24/7 stair wells. Done in 10/03. Total price of ~$4500. Total expected savings ~$2100. 15,731 kWh saved. Exist 5965W, new 4167W. T12/Mag to T8/Elec retrofit.

Have any measures been modified since their original implementation? If so, what is the new setting? Why was it changed?
Same as first interview. Tried measures 2 and 3, but they didn't work so returned to exist condition. Only programming changes, no cost because it was done under their JCI service contract.

1/23/04 More questions for Chief Engineer:

Since the Cx date, what other improvements have been done that can account for the 220,000 kWh of savings? Any major changes in occupancy? Has the computer center scaled back? What did you building do during the 2001 power crisis?
Occupancy – They have lost occupancy a litlle bit. As of Dec 03 at 90%, Nov 03 at 95.5% all the way back to Feb 03 at 97%. Therefore, during the period of our analysis, they averaged in the high 90's of occupancy. However, a resteraunt moved out 04/03, not sure

What did your facility do during the 2001 energy/demand crisis?
Diligently turned off all the unnecessary hallway lights.

Office4

Interview Notes:
Date: Oct.. 3, 2003.

Attend: Facility Manager, Chief Engineer,
Richard Green – SMUD, Naoya Motegi & Norman Bourassa – LBNL

Interview Questions

1. Please identify which of the following activities worked well with your commissioning project?
   Chief Engineer – Since he wasn't here during Cx inspections, he can't answer these.
   a. Issues identified and resolved in a timely manner
   b. Good communication among cx team members
   c. Quality of training received by the building staff
   d. Other: _________________

2. Describe positive impacts of commissioning.

3. Describe negative impacts of commissioning.

4. How do you justify commissioning costs?

Chief Engineer – Through operating Budget.

5. What are some lessons learned from this project?

Chief Engineer – Not much. The building operators have said that they didn't interact very much with the Cx Team.

6. Have you received commissioning services fro you facility since the 2001 report by ESS? Would you commission another building in the future? Why or why not?

Chief Engineer – Yes.

7. Do you expect to re-commission your building again? If so, what will trigger re-commissioning?

Chief Engineer – Yes. Likely through a combination of regular preventative maintenance (PM) checks of systems and the availability of external and internal funding for whole building Cx. He has recently written a new PM plan that calls for a regular regime of performance checks.

8. Do you have plans in place that will improve the persistence of commissioning benefits over time? If so, please describe.

Chief Engineer – Yes, the new PM Plan.

9. How did you become aware of the SMUD BAS Recommissioning program?
   SMUD Account Representative.

10. Do you know of any factors that could account for the large increase in energy consumption after November 2001?
    Chief Engineer – Must be an error in the billing data.

11. Do the tenants pay their utility bills directly?
    Facility Manager – We pays bills, then pass through to tenants. Two small exceptions, very small retail business on main floor who pay directly.

Do you consent to publishing an entry to the *CCC Case Study Protocol 1.0 Existing Building Commissioning* Database? If so, please have an authorized company official sign the Release Statement.
Facility Manager – Likely to be "yes".

Additional Notes:
Chief Engineer is the new Building Operation Engineer. Started approximate 6 months ago. Chief Engineer has a DX AC commissioning background, so he understands the value of whole building Cx.
Condenser water System:

Chief Engineer – He has discovered that there are no mud lines in the condenser system, so they are doing an evaluation of the water flow and quality:

- water treatment
- flow adjustment
- found some mud in the upper floor units, but not in the lower floors.

At the meeting, Facility Manager provided Naoya with missing electric and natural gas billing data.

Note: An entire floor has been vacant since beginning of 2003. Facility Manager gave me a brochure advertising ~34,000 sf of vacant space, all of 16th, portion of 15th and the ground floor.

Outstanding Question (12/16/03):

12/16/03 telephone follow up with Chief Engineer:

- Truthfully, he said the building was totally broken when he got there, now he's feeling better about getting on top of things.
- The next major issue is duct sealing. He estimates it will be a huge impact, because he can hear very loud leaks up in the plenum… almost anywhere he listens.

- He actually works for BA&T Engineers (a subsidiary of CB Ellis), so their time cost is actually marked up a bit when charged to CB Richard Ellis. He estimates the mark up is small ~ 15%.
- Took over the CW water treatment from a contractor. Did a complete drain and clean (during a holiday). Now lines are clean no problems. None of the units go down now.
- Had the CW pumps rebuilt. Found bad check valve in the bypass leg. There are four pumps, two in parallel running, 2 on backup. After valve was fixed, it corrected chronic low flow problems in remote branches.

Office5

Interview Notes:
Date: Oct. 10, 2003.

Attend: Property Manager, Stationary Engineer, Stationary Engineer (2)(No longer works at this site, but he was there during Cx site visits), Chief Engineer II (responsible for another building),
Naoya Motegi & Norman Bourassa – LBNL

Interview Questions

1. Please identify which of the following activities worked well with your commissioning project?
   Property Manager – N/A

   e. Issues identified and resolved in a timely manner
   f. Good communication among cx team members
   g. Quality of training received by the building staff
   h. Other: ________________

2. Describe positive impacts of commissioning.

3. Describe negative impacts of commissioning.

4. How do you justify commissioning costs?

Energy cost savings pay back.

5. What are some lessons learned from this project?

Learned that the original new construction Cx was inadequate and system problems were not found! For example: They found some sensors inside the walls, duct static problems, fan speed problems, etc.

6. Have you received commissioning services for this facility since the 2001 report by ESS?

No.

7. Do you expect to re-commission your building again? If so, what will trigger re-commissioning?

Yes. The trigger would be a major construction project, such as the upcoming controls system, or some external funding.

8. Do you have plans in place that will improve the persistence of commissioning benefits over time? If so, please describe.
   Chief Engineer II – We are always looking for ways to improve operation/performance. A Preventative Maintenance (PM) plan is in process, providing a regular semi-annual tune up of the equipment, but Cx type reviews

are not yet in the plans.

9. How did you become aware of the SMUD BAS Recommissioning program?
   SMUD account representative.

10. Do you know of any factors that could account for increase in energy consumption during 2000?
   Stationary Engineer – Year 2000 was the implementation year. 2001 was the first year with measure implemented

11. Are building management and maintenance contracted to a property management company?
   No, owned and maintained by owners.

12. Do the departments/tenants pay their utility bills directly?
   There is not energy charge pass through to the department tenants. Only a straight $/sf lease charge to the department budgets.

Do you consent to publishing an entry to the *CCC Case Study Protocol 1.0 Existing Building Commissioning* Database? If so, please have an authorized company official sign the Release Statement.
Yes.

Additional Notes:
Stationary Engineer:
Most the recommended measures from the ESS report are implemented. He read the report yesterday and he thought it was good, well done. (Note: Stationary Engineer was not at this facility when the Cx process occurred.)

Stationary Engineer & Property Manager:
They both provide an extended description of problematic duct static pressure issues as a result of:

- BAS program problems
- Pneumatic to DDC interface problems
- Barometric pressure sensor problems

Property Manager:
A new BAS system is in design right now, with construction scheduled for July 2004.

They have received an EnergyStar rating, with a score of 90.

Chief Engineer II, regarding New Construction Cx:
He comments that even though on paper a Cx looks good, in practice the Cx process doesn't go well and many of the systems do not work! Most often the Cx plan doesn't work -> too late -> occupancy occurs without Cx.

EnerLink system is set up for whole building power only.

Outstanding Questions (2/4/04):
Property Manager or Stationary Engineer Answers provided in 2/4/04 email from Property Manager.

What is the estimate of time/cost to the building operations staff to accommodate/escort the Cx Agents?
No Answer provided.

What did your facility do during the 2001 energy/demand crisis?
No Answer provided.

How much time/cost do estimate your staff expended for the measure implementation? (Sensor calibration, SF 1,2 & SF 3,4 CC problem) Have any other measures been done since we talked?
After having a chance to speak to those who were involved with this retro-commissioning we arrived at around $15k for these improvements. The lions share of this would be the hiring of BAS programmer Dick McClay w/KISSCO Inc. Hope this helps, Property Manager

Additions to the site survey questions, provided by Property Manager in 2/4/04 email. (in red)

1. Please identify which of the following activities worked well with your commissioning project?
   Property Manager – N/A

   i. Issues identified and resolved in a timely manner
   j. Good communication among cx team members
   k. Quality of training received by the building staff
   l. Other: __________________

2. Describe positive impacts of commissioning.
   It looked at building design specification and determine if there was ways to save more energy. Identified deficiencies in the system such as having the First floor operate more independent of the main building system. Add more centralize off-hours HVAC. Help to reduce State of California mandate to cut back on energy during the energy shortage.
3. Describe negative impacts of commissioning.
   Had to reintroduce to the tenants HVAC State of California guidelines.
4. How do you justify commissioning costs?
   Energy cost savings pay back.

5. What are some lessons learned from this project?

Learned that the original new construction Cx was inadequate and system problems were not found! For example: They found some sensors inside the walls, duct static problems, fan speed problems, etc. Building Automatic System deficiencies.

6. Have you received commissioning services for this facility since the 2001 report by ESS?

No.

7. Do you expect to re-commission your building again? If so, what will trigger re-commissioning?

Yes. The trigger would be a major construction project, such as the upcoming controls system, or some external funding.

8. Do you have plans in place that will improve the persistence of commissioning benefits over time? If so, please describe.
   Chief Engineer II – We are always looking for ways to improve operation/performance. A Preventative Maintenance (PM) plan is in process, providing a regular semi-annual tune up of the equipment, but Cx type reviews are not yet in the plans. Add heat to Mezzanine. Prevent wasting of heat through telephone/electric closet exhaust fans.

9. How did you become aware of the SMUD BAS Recommissioning program?
   SMUD account representative.

10. Do you know of any factors that could account for increase in energy consumption during 2000?
    Stationary Engineer – Year 2000 was the implementation year. 2001 was the first year with measure implemented

11. Are building management and maintenance contracted to a property management company?
    DGS owned and maintained.

12. Are there Departments or other tenants in facility that share a portion of the utility costs?
    There is not energy charge pass through to the department tenants. Only a straight $/sf lease charge to the department budgets.

Do you consent to publishing an entry to the *CCC Case Study Protocol 1.0 Existing Building Commissioning* Database? If so, please have an authorized company official sign the Release Statement.
Yes.

Office6

Interview Notes:
Date: Oct. 31, 2003.

Attend: Building Management Technician,
Richard Green – SMUD, Naoya Motegi & Norman Bourassa – LBNL

Interview Questions

1. Please identify which of the following activities worked well with your commissioning project?

    a. Issues identified and resolved in a timely manner
    b. Good communication among cx team members
    Building Management Technician – This was the most notable.
    c. Quality of training received by the building staff
    d. Other: ________________

2. Describe positive impacts of commissioning.

Building Management Technician – "We saw a lowering of our energy consumption. We also saw the we were already operating pretty well."

3. Describe negative impacts of commissioning.

Building Management Technician – It used up staff time.

4. How do you justify commissioning costs?

Building Management Technician – "Energy savings and as a learning & training tool."

5. What are some lessons learned from this project?

Building Management Technician –

- We need more training for our operators
- That we need to pay more attention to daily operations
- We need more preventative maintenance on equipment

6. Has the ongoing Facility Dynamics controls commissioning project affected any of the 2000 SMUD Recommissioning recommendations?

Building Management Technician – "Not that I am aware of. However they may as FDE is looking at the entire sequence of operations and will be making changes."

7. Do you expect to re-commission your building again? If so, what will trigger re-commissioning?

Building Management Technician – " The FD Review is in our view a Recommissioning."

8. Do you have plans in place that will improve the persistence of commissioning benefits over time? If so, please describe.

Building Management Technician – "We plan to retain the services of FDE. These services include regular checks & reviews by FDE staff."

9. How did you become aware of the SMUD BAS Recommissioning program?
Building Management Technician – "I was contacted by SMUD."

10. Are building management and maintenance contracted to a property management company?
Building Management Technician – "Yes, owned by GSA. Building maintenance is contracted."

11. Do the tenants pay their utility bills directly?
Building Management Technician – GSA energy bills go to Kansas City. Building Management Technician never sees them. EnerLink used to be set up, but their interface computer has died and there is no budget to replace it.

Do you consent to publishing an entry to the *CCC Case Study Protocol 1.0 Existing Building Commissioning* Database? If so, please have an authorized company official sign the Release Statement.
Building Management Technician – Ask someone else in regional office.

Additional Notes:
Building Management Technician:
Facility Dynamics, has been on permanent retainer. He comes in once every month to fix/adjust the Metasys settings. This has replaced the service contract from JCI, which Building Management Technician was not happy with.

Note: Richard will get the first nine months of billing data the we are missing. It is easier for him to get than it is for Building Management Technician. However, Building Management Technician says that ~2/3 of the facility was under major renovation during most of the year.

They had very good interaction with the Cx agent. Building Management Technician's building operators learned a lot from the process.

In Building Management Technician's view, one of the most important roles for the CX agent to remember is that it is also a learning/teaching process and they should be open to that and not have a "you don't know as much as me, so out of my way" attitude.

Outstanding Questions (2/10/04):
For Building Management Technician - Answers Provided 2/10/04

What is the estimate of time/cost to the building operations staff to accommodate/escort the Cx Agents?
40 hrs @ $42.5/hr = ~ $1700

What did your facility do during the 2001 energy/demand crisis?
Implemented a plan where we did group setpoint changes:

- Summer raise temp setpoints by an average of ~ 2 Deg F. Gave immediate peak reduction, but building began loading up again as temps drifted ~ only hours of delay due low thermal mass single pane windows.
- Did some de-lamping T-8 and compact fluorescents

Have any measures been modified since their original implementation? If so, what is the new setting? Why was it changed?

Yes, Facility Dynamics has been tweaking the Cx recommendations on three BAS related measures (No.4, 7 & 10)

New Development: Recently acquired GSA funding for a complete Retro-Cx of this building..